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NOTE

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Sir Isaac Newton: the Man and his Influence.

By A D Ritchie, M A

It was dramatically appropriate that Newton should have been born at the end of the year in which Galileo died For the Englishman completed the work the Florentine had begun and in an age of giants Newton and Galileo stood head and shoulders above all contemporary men of science Though when at Christmas 1642 in the first gloomy winter of the Civil War a premature and sickly infant was born at the little manor house of Woolsthorpe in Lincolnshire nobody could have predicted his importance to the world least of all the astrologers Before the advent of Newton it was still not utterly unreasonable to think that the stars in their courses might control the fates of men after him utterly unreasonable Even the geneticist arguing on a sounder basis would not have suggested more than respectable mediocrity For none of Newton's forbears so far as known were in any way distinguished though they were of that sound healthy farming stock which seems so often to possess a reserve of latent talent Isaac Newton claimed to be, and was Lord of the Manor of Woolsthorpe but the annual value of the manor was only £30 so that his family were in fact working farmers somewhat impoverished through the improvidence of his father and perhaps also by the disturbances of the Civil War though later on in comfortable circumstances Still Newton had to go up to Cambridge as a Subsizar—a kind of inferior scholar who performed light but menial services for the Fellows of the College Nevertheless it is a mistake to think of him—except for these early years—as the impoverished and neglected scholar He never seems to have thought of himself in that light and was open-handed and generous in money matters It is also a mistake to make him out the absent minded and eccentric professor of popular fiction though he did to a considerable extent live as a recluse

One of the difficulties in the way of arriving at a just estimate of Newton's character is the paucity of genuine contemporary evidence and the prolific crop of legend Of course given a man of unusual character and obviously great powers, who keeps himself rather remote from the public gaze, the soil is ready for the growth of legend Undergraduate wits were at

work in Cambridge and later the irrepressible M Voltaire in London Fortunately L T More s careful and well documented biography* is available to eradicate these weeds and to help us to see something, though incompletely of the kind of man he was Forget for a moment any stories you may have heard about making a hole in the door for the cat to go through and then a smaller one for the kittens about boiling his watch in the saucepan and holding the egg in his hand Forget even the more likely story about leaving the hot supper brought to him at night and eating it cold for breakfast next morning Forget also the efforts of the hagiologists to turn him into a stained glass figure Consider instead a few authentic and public facts At a time of grave political crisis when the liberties of Cambridge University were threatened by arbitrary and oppressive acts of King James II Newton took a leading if not the leading part in opposing the King though he was not a ready speaker and was easily embarrassed in public This he did very soon after the tremendous effort of writing his *Principia* in about 18 months When the Convention Parliament of 1688 was elected to regularise the accession of William and Mary, settle the succession to the throne and generally order the affairs of the country after the Revolution, Newton was elected member for Cambridge University It is evident that people trusted Newton as a man of affairs and relied on his judgment and it is evident that their confidence was not misplaced We know the bare fact but unfortunately we know nothing of what lay behind it, because we only know of Newton hitherto as a scholar immersed in academic studies, with few friends and apparently very few intimate friends if any, who for years hardly ever left Cambridge except to visit his country home and family

In 1695 when Montague as Chancellor of the Exchequer, was striving to straighten out the disordered finances of the country, one of his major tasks was to replace the clipped and debased silver coinage by a new currency of standard weight and fineness and with milled edges to stop clipping He knew it was no use issuing new good coins while the bad ones circulated, because the new ones would just be hoarded or sold abroad

* Isaac Newton a Biography by Louis Trenchard More New York and London 1934

The only thing to do was to recall the whole of the old coinage to be replaced at its face value by new, and to set a time limit after which old coins would not have any exchange value. This meant in any case a considerable loss to the Exchequer in making good the deficiency of silver; also the possibility of a grave financial crisis during the time lag between recall and reissue. The country was at war. The Government had many enemies only too ready to aggravate a financial crisis if they could. The work the Mint had to do was to melt down the old coin, assay the metal, refine it if necessary, and then coin it, and all as quickly as possible. It meant handling far larger quantities and working far faster than had ever been done before. Whoever was in charge of the Mint had to be a good organiser with some technical knowledge of assaying and metallurgy, and above all completely trustworthy, a staunch Whig immune from Tory bribes or persuasions. Montague turned to his Cambridge friend Newton as the man needed and appointed him Warden of the Mint. Again we know very little of the details of the work, but we do know that the work was effectively done and that Newton refused tempting offers intended to get him away from the Mint. After the crisis was over Newton became Master of the Mint in which position he had a higher salary and much less work. This post he held until his death. After coming to London Newton did little more scientific work apart from what went into the second edition of the *Principia*. It is true he published his *Opticks* in 1704, but probably all the experimental work had been done long before. It has always seemed a mystery why the world's greatest experimental and theoretical physicist, after thirty years devoted to research, should abandon it while apparently at the height of his powers. He did not abandon it just for a time to do a service to the State and help his friends Montague, Somers and Locke, but for good and all.

To consider the matter we must go back to Newton's earliest published scientific work on optics. This involved him in prolonged controversy with Hooke and others. Unfortunately Oldenburg, the Secretary of the Royal Society, disliked Hooke and instead of acting as peacemaker did the opposite. Controversy should be carried on by those who are like Socrates, of equal temper, thick skinned, with a robust sense of humour

They will play the game according to the rules. Newton was not only excessively sensitive but secretive and suspicious of all but the few friends he trusted He lacked the virtue of suffering fools gladly. L. T. More* suggests that the defects of Newton's character may have been aggravated by childhood experiences, when as a baby he was left alone with his grandmother in a solitary house in a disputed region during the Civil War. This is very probable. In any case he had these defects. In addition Newton was always quite sure he was right justifiably in the controversy on optics, but not always later. Unlike a complete and consistent recluse, such as Cavendish, he did care what people thought about his work and was not indifferent to fame ; in fact in later years he seems to have been too much influenced by flatterers. The nett result was that Newton was frequently and for long periods involved in scientific controversy, hated it, lost his temper and sometimes behaved badly. That was why he thought science a hard taskmaster.

Apart from all this it is almost certainly true that Newton's primary interests were not scientific ; but he was so constituted that if presented with a specific problem which seemed at all interesting and in any way soluble he could not rest until he had found a solution. It is quite clear that he thought little of pure mathematics ; but show him a physical problem in mathematical form, and he could and would solve it with startling ease and quickness.

What, then, were Newton's primary interests? Remember that his first and principal friend in Cambridge, until that friend's early death, was his teacher Isaac Barrow, a brilliant mathematician who willingly gave up the Lucasian Professorship to Newton so as to be free to pursue his theological studies. Newton's other chief friend, so far as is known, was Henry More, the Platonist, a theologian and a mystic. Remember too, the seventeenth century was a religious age and Newton in any case a serious-minded and religious man. There can be little doubt that his primary interests were religious and theological. Like Boyle, Hooke and other leading thinkers of the day, Newton valued science mainly because he considered that it revealed

* loc. cit. p. 16.

the works and therefore the nature of God From the first he devoted a great deal of time and labour to theological studies In the main he accepted the assumptions of his day He was however in advance of his time in questioning on historical grounds the authenticity of certain passages in the New Testament He did not publish this work during his lifetime for fear of accusations of heresy because these passages provided generally quoted scriptural authority for the doctrine of the Trinity It was probably these doctrinal difficulties that made him refuse to take Orders, though as a layman he felt he could still conscientously remain a member of the Church of England The main purpose of his theological studies was to uphold Protestantism and refute the claims of the Roman Church The historical study of the doctrine of the Trinity was made for this purpose , as also were his elaborate studies of the Book of Daniel and the Apocalypse of St John In these matters he was entirely the child of the period He considered that the writers of these works were predicting events of the distant future (distant at the time of writing) and he claimed to find evidence that the final destruction of the Roman Church was among these predictions

For Newton's method of interpreting the Book of Daniel, as for his studies of ancient chronology, one cannot say more than that his attitude was essentially that of his contemporaries and that he differed from others chiefly in working things out more systematically and industriously But against the criticism, sometimes made in recent times, that his interest in the doctrine of the Trinity was a trivial one for a man of science, it is necessary to protest For Newton, indeed, it was science that seemed trivial, dealing as it does with mere details of the transient world, and theology that was serious, dealing as it does with things eternal If you have any kind of belief in an immaterial or spiritual world, then the doctrine of the Trinity is an attempt, however imperfect, to give an account of that world and must be taken seriously ; especially by one who was endeavouring, as Newton was, to find some completely general law of the subordinate material world The weakness of Newton's philosophy lay elsewhere, where Leibniz indicated it. Newton's system of the material world was purely mechanical and on his view God

is the mechanic who makes and operates the machine. In this he followed Descartes. But can a purely immaterial mechanic have any connection with a purely material machine? Either God is material, as Spinoza said (to be dubbed atheist in consequence), or else the material world is not purely mechanical, as Leibniz said. Most of those who in later times have accepted Newton's system fastened their attention on the machine and ignored or denied the mechanic, assuming the machine to have made itself; so that in fact the theory has led to materialism and atheism, far as this was from Newton's intention. It must be said on the other side, that Leibniz's own theory, though immune from this criticism, was unworkable and useless from the point of view of seventeenth and eighteenth century science, while Newton's was supremely workable and useful; and is in fact still the working theory of all science except certain special departments of theoretical physics. I shall return again to what it was Newton had accomplished, in the meantime a little more about his personal history.

Newton's labours for a year and a half while writing the *Principia* have been described by his amanuensis He worked almost continuously day and night, with a few hours snatched for sleep and a little food gulped down at irregular and infrequent intervals. His only relaxation was to go and work equally hard in his chemical laboratory. Almost as soon as he had seen the book through the press Newton was plunged into public affairs for the first time in his life, in the conflict of the University with James II, and after as member of parliament. It was just at this time, in 1688, that his friend Henry More died. The next year his mother, to whom he was deeply attached and whom he nursed assiduously in her last illness, died too. It would be surprising if the strain of these years had not affected him. Later, in 1693, he did suffer a temporary mental derangement, something like persecution mania and very likely loss of memory too. It is impossible to say how serious it was (it produced a whole crop of rumours), but to all appearances he recovered quickly and completely, and lived to enjoy a vigorous old age; such as nobody so negligent of the rules of health is entitled to. By rights he should have been a hopeless invalid at fifty. Still, though he recovered his health he may have felt tired and,

particularly, tired of scientific work after the *Principia* was published, and unwilling to undertake anything more. He had of course a problem on hand, only dealt with cursorily in the first edition of the *Principia*, which he worked at for some time. This was the problem of the moon's perturbations, which Newton said gave him a headache and is still a bugbear of the mathematician. The moon's path instead of being a steady and graceful progress, such as befits a lady, is more like the staggering gait of a drunkard. Newton's theory could account roughly for the general character of the path , could it account for it accurately by explaining the perturbations, without leaving out any unexplained residue ? It was an interesting test case for the theory. It was also considered to be an urgent practical problem because a satisfactory lunar theory, which would enable its apparent place among the fixed stars to be predicted accurately, would solve the outstanding problem of navigation—the determination of longitude. Newton, like all his contemporaries, was aware of the practical possibilities of physical science and eager to promote them. Lunar theory would have provided full time occupation for most men, but not for Newton. So that in spite of this work and in spite of the publication of the *Opticks*, it is true enough to say that after 1687 he gave up the pursuit of science ; certainly he started nothing new. Was it that after his illness he had lost initiative ? Was it, as he said, that science was a hard taskmaster ? Or was it, perhaps, that he knew he had shot his bolt ? After all, the universal mechanical system of the world can only be discovered once. The nature of light can only be discovered once. The harvest had been cut by him and carried ; might he not leave the gleaning of the stubble to the geese ?

There is a further point. Newton had worked hard and long at experimental chemistry (or alchemy, for in the seventeenth century they were still much the same). He left no record of results, presumably because they were disappointing. Whatever his aim may have been, by this time he may have decided he could not realise it. In fact, the day of chemistry had not yet come. The first glimmer of light was due to Newton's friend Boyle, but the true dawn came a century later with Lavoisier and Dalton.

Shakespeare retired to Stratford as soon as he had enough money to do so, and apparently thought more of becoming a country gentleman than of all his works; a thoroughly English and, if you like, snobbish attitude. Newton seems to have felt much the same as Shakespeare and was pleased to take the place befitting a country squire in the social and political life of London. Apparently he felt no regrets for his life of seclusion and scientific research in Cambridge. It must be said too that most of his friends there were dead or had departed, and few of the newer generation were of the same calibre. The University was already settling down to the long slumbers of the eighteenth century.

I must turn now to say something of the *Principia*, always recognised as the greatest single scientific work ever written. The germ of this book, but only the germ, was there in the famous episode of the falling apple in 1666. The episode may have existed only in the imagination of Voltaire, but it was well imagined. The youthful Newton meditating in his orchard at Woolsthorpe considered what it was Galileo had discovered. First of all that any terrestrial body if left to itself, subject to no external force, remains at rest or goes on moving with uniform velocity. If I let go a stone I am holding it is not left to itself but is subject to a force directed towards the earth which alters its state of rest or motion ("force" here means the Newtonian notion: that which alters velocity). If I just drop the stone it approaches the earth at a speed governed by the rule of equal acceleration in equal times (neglecting air resistance). The rule is the same for all bodies. If I throw the stone, I impart another and constant velocity to it and the stone's path (again neglecting air resistance) is compounded of this constant velocity and the same acceleration towards the earth. Its path, as Galileo found, is then a parabola. The new idea that occurred to Newton now was that perhaps the moon in circling round the earth behaves like the thrown stone; like a stone that has been thrown with such violence that although continuously dropping towards the earth its tangential velocity keeps it moving away just as fast as it drops, so that it moves round in a circle, or very nearly in a circle. Newton made some rough calculations and, as he himself said in an account written in 1714, "found them answer pretty nearly." The story about

his first disappointment due to using an erroneous estimate of the earth's circumference, and hence of the moon's distance in terrestrial units, is a mare's nest, as I think More shows conclusively. I have no time to discuss it here and must refer any one who is doubtful to his book.* Newton had made here the first and therefore most difficult step towards his great synthesis, but no more. There were plenty of other steps and twenty years was not too long for them. I can imagine one of our great research laboratories with its team of fifty highly trained workers taking longer—a couple of centuries perhaps.

One such step was to apply the same notion to the solar system assuming the planets are falling towards the sun. Kepler had shown the paths to be elliptical and found a general rule relating speed and size of orbit. It had occurred to several people, including Hooke, Wren and Halley, that any centripetal force was likely to vary inversely as the square of the distance, a fairly obvious surmise from the geometrical properties of concentric spheres. But none of them could solve the mathematical problem of showing that such a force would give rise to Kepler's Laws. Halley, when he went to consult Newton in 1684, found that he had already solved the problem. It was this information that made him urge Newton to complete and publish his theory. There were other problems too. During this period Providence supplied mankind with unusually numerous and splendid comets, apparently as test objects for Newton's theory, and they had to be dealt with. A very important and difficult mathematical problem had to be solved. For distant bodies such as sun and planets, it could be safely assumed that they behaved like massive points; but for the earth's action on bodies near its surface it was far from obvious. Newton, however, was able to prove that the earth's gravitational attraction was the same as that of an equal mass occupying its centre of gravity. Still another problem was that of a body beneath the earth's surface (*e.g.* falling down a mine shaft), necessary to show that no absurd consequences followed from the theory.

For most men this would have been enough to demonstrate that there was a universal system of mechanical laws and a

* loc. cit. p. 289. See also the notes in F. Cajori's Edition of Motte's Translation of the *Principia*, 1934.

universal force, that of gravitation; but not for Newton. He threw in the explanation of the earth's figure, the precession of equinoxes and the elements of the gravitational theory of tides, showing incidentally that he had studied the available information on tidal phenomena over the whole known world. He devoted the Second Book to developing the theory of hydrodynamics (and a few other things too) for the principal purpose of showing that Descartes' theory of vortices could not possibly account for the observed laws of motion. This theory of Descartes has been deservedly forgotten, but it was very popular at the time. According to him the planets moved in a manner analogous to floating bodies whirled round in the eddies of a stream. Besides the mathematical theory there is much valuable experimental work in the Second Book. What seem to be the first quantitative experiments on viscosity are there. More important though is a careful and extensive series of experiments made by filling the bob of a pendulum with different materials to show that gravity depends solely on the mass of bodies and is independent of density and of any qualitative differences.

Not content with gathering the crop that had come to maturity Newton also planted what was needed for next season's harvest.

In developing his theory Newton used a private mathematical method of his own, that he had begun to develop during those two wonderful years he spent at home to escape the plague, when he laid the foundation of all his discoveries. But for purposes of exposition he translated everything into the classical geometrical form. The whole mathematical apparatus for this had to be developed and included in the book. It is this work of translation more than anything else that makes the writing of the *Principia* in eighteenth months such an incredible feat. He had written the small tract *De Motu* which corresponds to the First Book and may have had the other main points worked out, but almost certainly in his own notation. It would appear therefore that every mathematical proposition in Book II and III of the *Principia* and its proof was worked out *de novo* during that time.

I think it is clear that even if Newton had done nothing else between 1666 and his beginning to write in 1684 but collect the

data and work out the mathematics required for the *Principia* he would have been fairly well occupied. There is no mystery about the twenty years' delay. Newton was quite right not to publish until his work was complete; it is a pity so few are of the same mind. But not only did he not wish to publish anything incomplete, he was also reluctant to publish anything at all. His correspondence with Halley, who bore the cost of printing the *Principia*, shows a curious and unpleasant indifference about the work that can only be excused by the mental and physical strain of his efforts.

There is a further puzzle I must touch on, though I am not competent to deal with it, as it involves difficult points in the history of mathematics. Newton seemed to want to keep to himself his great mathematical discovery of an algebraic method for dealing with continuously varying quantities, as if it was private property, and yet to claim public recognition as its discoverer. It was this that led to the quarrel with Leibniz in later life, which was carried on even after Leibniz's death. Both these great men behaved very badly; they not only lost their tempers; they cheated also Newton's behaviour was perhaps a shade worse than Leibniz's. It is only fair to say, however, that at first they both behaved properly; Newton cold but correct; Leibniz friendly and appreciative. It was only later when they were egged on by unscrupulous and foolish friends that trouble occurred. Newton's secretiveness has seemed to many sheer perversity and far more than can be accounted for by dislike of controversy. Another thing that is difficult to understand is that Newton apparently failed to see that Leibniz's notation, the one now universally used, was better than his own; for in mathematics notation is half the battle or more. I think some light is thrown on the subject by a remark of Newton's, late in life, to the effect that the new algebraic methods introduced by Descartes lacked the rigor of the classical geometrical methods. This confirms the impression one gets from *scholia* in the *Principia*, where he says that the geometrical method of limits he there develops to do a good deal of the work his fluxions could do, is a method that could be shown to be fully exact and rigorously proved after the classical model, but that complete proofs by *reductio ad absurdum* would be

extremely lengthy He shows also that he was highly suspicious of the whole notion of infinitesimals a notion he probably thought was necessarily involved in the method of fluxions It looks in fact as though Newton was worried by the same scruples that worried the ancient Greeks, that if a length is taken to be a numerical aggregate, either it must contain a finite number of finite units or an infinite number of units of zero magnitude Both alternatives are absurd Therefore the only escape is to use strictly Euclidean methods, which, in accordance with Plato's view, dispense with the assumption that a length is an aggregate of parts and avoid using arithmetical, *i e* algebraic methods for purposes of proof The only modification of Euclid required is the use of the notion of continuity and of limiting values His method of fluxions, therefore, he may have considered as no more than a method of approximation, a convenient dodge or short cut to the discovery of propositions, which, if proved, must be proved by classical methods If the mathematician's business in his published work is with proof, it is a mistake to publish mere dodges It is also possible that Newton was one of those rare individuals who have an intuitive grasp of the solution of mathematical problems largely independent of any special notation or formal statement, so that for him notation and details of method were not essential at all At any rate Newton did not publish his method until after Leibniz had published his very fully, and shown how it could be used When people began to make a fuss about Leibniz Newton was naturally, though not very reasonably, annoyed

However, this is really a digression There are two more comments to be made on the *Principia* First, that it took a hundred years for the scientific world to digest fully and develop completely the ideas contained in this work Secondly, what was it Newton had done? He had solved at last the technical problem set by Plato to his pupils in the fourth century B C , to find a geometrical construction which would account for the apparent motions of the planets Newton did it as completely and as elegantly as was possible in terms of the information and ideas of his time Eudoxus, Plato's pupil, had found a rough and ready solution, afterwards in a revised form known as the Ptolemaic system , Kepler had found a much more exact

solution but one that still had to introduce a number of arbitrary and unrelated factors. Newton had reduced it all to two principles; the laws of motion, which are really one law explaining what is meant by inertia and force, how they are related and how they are measured; and then the law of gravity. But he had done very much more than solve Plato's problem, for these are the laws that govern all events that occur in space and time everywhere; the movements of comets, the tides, the winds, the flow of rivers, the waves of the sea, the shapes of mountains and valleys, the wagging of the pendulum, the flight of the bullet, the stability of houses and bridges. When we consider the movements of the compass needle, the flight of the swallow and the running of the deer other complicating factors come in, but Newton's laws are there too, as a universal ground bass on which other changing themes are superimposed. All this is startling enough but it is a purely technical scientific matter. Newton's scientific discoveries had also the effect of upsetting completely some of men's general philosophical conceptions; a large part of traditional cosmology, already shaken by Galileo and Kepler and others People had been accustomed to draw a sharp distinction between what happened on earth where things are transient, perishable, imperfect and largely disorderly, and what happens up above in "the heavens" where everything is perpetual, perfect, orderly and divine. It is true some of the more daring of the Greeks of the fifth Century had disputed this view, but the weighty authority of Plato and Aristotle was thrown into the scale of traditional belief and men rested secure in their dogmatic slumbers. Now Newton had wakened them up. Instead of the universe being divided into two spheres, earthly and heavenly, men had to choose between two philosophies. Either everything was of the earth earthy and there were no heavens and nothing divine, or else earthly and human things had as good a right to be considered heavenly and divine as anything else. What had been banished for good as a possible view for reasonable men was any kind of supernatural materialism, the view that the spiritual is a specially fine and thin kind of matter which may be supposed capable of anything; though that is still the favourite theory of the superstitious and the thoughtless. Either we must be thorough-going materialists,

in the strict sense of saying nothing at all exists except matter in motion and matter has no intrinsic properties except that capacity for locomotion—a difficult theory—or else we have to find an alternative. Fortunately there are plenty of alternatives and I need not say more about them at the moment.

I have still to deal with Newton's work on optics and some important points arising out of it. In his day the experimental study of optics was a severe test of mechanical skill, as the experimenter had to grind his own lenses and set up his apparatus himself without external aids of any sort. Newton went further and built himself a furnace to melt up his own glass. Undoubtedly he owed a great deal to his childhood hobby of making models and mechanical toys. For the experimentalist mechanical skill is half the battle; the other half is seeing what experiments need to be done, asking the right kind of question.

There can be little doubt that Newton's optical investigations sprang from his desire to improve on the Galilean telescope. His first efforts were frustrated by his not being able to produce lenses free of chromatic aberration; there was always a fuzziness of the image due to a fringe of colours, so that increased magnification did not reveal more detail. His enquiry into the mode of formation of the coloured fringe led to his discovering that ordinary white light is composite, consisting of rays of different refrangibility, which are sorted out by passing the light through a prism. A pure ray of light, that is to say one which is all refracted by the same amount, is coloured and there is a constant relation between colour and refrangibility shown in the colours of the spectrum, from red the least, to violet the most refracted. The experimental evidence for this is set out with masterly completeness and precision in the first part of the *Opticks*, the only part I can deal with here.

Newton in his own work was perfectly clear about an important distinction, not made by any one before and not always sufficiently appreciated since, between the physical properties of light and phenomena of visual perception. It is the first only which are the subject matter of physics; the second are the subject matter of physiology and psychology and are of no interest to the physicist as such, except so far as they draw his attention to the defects and limitations of the human eye

considered as a detector of light. For physics the eye is just that and no more. In principle it could be replaced by other detectors and all the physical phenomena of light could be studied (though with difficulty) by the totally blind. One source of controversy between Newton and others was their failure to understand this distinction.

The other and more important source of controversy was on the use and abuse of what Newton called "hypotheses" (in contrast with theories and laws). I should like to dwell a little on this matter although it is a difficult one because Newton was the only "modern" among his contemporaries who were still partly "medieval" in their views. But Newton has often been misunderstood because of the extreme brevity of the statements in the *Opticks* and *Principia*. Newton criticised his contemporaries because they preferred speculation about imaginary causes of the physical phenomena of light to the precise and systematic examination of these phenomena themselves. In fact sometimes they allowed their speculative conceptions to blind them to facts.

Given any limited set of phenomena it is always possible to imagine a number of different alternative mechanisms capable of causing them, though few people having thought of one take the trouble to go on and think of any other. So long as there is no evidence on which to base a decision between alternatives they are strictly superfluous to a scientific account and are not necessarily better than the justly derided "occult qualities" of the Schoolmen. They are in fact only "occult qualities" of a mechanical kind. What is necessary for the scientific account is that it should be based upon the widest, most systematic and most precise acquaintance with fact that is attainable and should be stated in general terms. To take a case. Anybody who repeats Newton's experiments on the refraction of sunlight using his methods will get the same results and will have to arrive at the same conclusion on the basis of that evidence. This is what follows from any properly conducted and properly reported observation. Unless it can be put in the form, that anybody who does so and so will get such a result it is only a historical curiosity of no scientific interest. Of course, an observer who uses more refined methods

than Newton can obtain results of greater precision. By using other methods he can extend the observations to radiation beyond the visible spectrum. Such observations add to Newton's work, supplement and improve on it, but take nothing away from it ; it still remains as permanent as anything in science.

Speculations, Newton's "hypotheses," about the possible causes of the phenomena of light on the other hand are less permanent. Very little that anyone in Newton's day had to say about waves or corpuscles as causes of light is of importance now. We can be quite sure too that similar speculation to-day, so far as it deals with matters incapable of experimental test, will be a source of amusement 200 years hence.

The same is true of Newton's system of Mechanics and Gravitation. Newton's laws have been improved upon but not superseded. For all bodies that are not extremely large or extremely small or moving extremely fast, and for all times not extremely long or extremely short, in effect for all bodies and motions he or any one else knew about till the present century, they provide a very close approximation formulated in the simplest way and are still invariably used. The only part of his system that can be said to be superseded or disposed of is the "hypothesis" he found he needed, though he had doubts about it ; the hypothesis of absolute and uniform space. Even that was a masterly simplification. It sufficed for all scientific thinking for 200 years and suffices for most at the present day. Only a few philosophers have been liable to headache on account of it.

Some nineteenth-century thinkers went much further than Newton and roundly condemned all hypotheses or speculative constructions as radically vicious, simply because they are capable of misuse. That is a mistake. They have an important place as long as they are used for their proper purposes, as props or aids to the understanding and as the means of suggesting the kind of experiment to be done. They are not to be taken as substitutes for fact, but as going ahead of actual known fact and pointing to possible fact. It is through them that questions are asked which experience can answer. If they are well framed some part of them becomes in course of time incorporated in experience. Even if badly framed they may still be useful.

One man (A) thinks that on the other side of the mountains the beds of the streams are filled with nuggets of gold, and therefore he goes to look. He will be quite wrong about the nuggets but he will find out what is there, whatever it is. Another man (B) says that nobody has ever seen the other side of the mountains therefore nothing can possibly exist there. He will not go to look and will never find out anything. A third man (C) is sceptical about A's gold nuggets Unless his scepticism is positive and leads him to go and see, it is no better than B's dogmatic denial. The more we speculate the better, as long as the speculations are an incitement to find out something new, not a substitute for it. As a very shrewd medical thinker, Wilfred Trotter, said, "It is poverty rather than fertility of ideas that causes them to be used as a substitute for experiment, to be fought for with prejudice or decried with passion. When ideas are freely current they keep science fresh and living and are in no danger of ceasing to be the nimble and trusty servants of truth."* It was just because of his great fertility in ideas that Newton was able to see both the uses and the limitations of those hypotheses which less fertile minds tended to misuse.

On this matter of "hypotheses" he was undoubtedly right, though his controversial methods were not always defensible, and in one case at least helped him to persist in a serious error. This was that he thought it was impossible to construct lenses free of chromatic aberration. True, his error led him to construct the first reflecting telescope—Gregory had designed a reflecting telescope but had not made it. The reflecting telescope has been a tremendous success, for which Newton well deserved his Fellowship of the Royal Society, although it arose from a mistake. It is not easy to understand how it was that Newton failed to discover that different kinds of glass have different dispersive powers for colour, whereby it is possible to make a compound lens of two different glasses with negligible chromatic aberration. He made observations on refraction with a large number of different kinds of material, in the course of which one would have thought he would have come across the phenomenon. Actually one of Newton's continental critics reported an observation which should have given him a clue, but by that

* British Medical Journal, July 26, 1930, p. 132.

time he was thoroughly out of temper and not disposed to listen to what anybody else said. So the first achromatic lens was made by Hall shortly after Newton's death and this opportunity was missed. We can console ourselves with the thought that even the greatest are not immune from error and it can still be said with truth "Show me the man who has made no mistake and I will show you the man who has made no discoveries."

Newton was lucky in living at the epoch when the scientific world was ready for just such a synthetic effort as he was uniquely capable of making; lucky in finding a teacher, such as Barrow, supremely well fitted to inform and stimulate him; lucky in finding leisure and opportunity to pursue the argument wherever it might lead (as Plato says); lucky in enjoying robust health to carry him through. But when we have discounted all that external circumstances brought to him it remains true that he possessed in the most eminent degree different and distinct powers of mind that are seldom found together at all. Einstein has put the matter as neatly as it can be, and I cannot do better than conclude with the tribute of the greatest theorist of modern times "In one person Newton combined the experimenter, the theorist, the mechanic, and, not least, the artist in expression."

The Autonomy of Science.

By M. Polanyi

I

To-day the position of science which was unquestionably accepted in the Western countries for the last 300 years or so, has been challenged by an authoritarian doctrine.

It is difficult to trace a complete authoritative statement of the argument used in support of the state control of science. But I believe that in its most precise form this argument would run about as follows. No scientific statement is absolutely valid for there are always some underlying assumptions present the acceptance of which represents an arbitrary act of faith. Arbitrariness prevails once more when scientists choose to pursue research in any one direction rather than another. Since the contents of science and the progress of science both vitally concern the community as a whole, it is wrong to allow decisions affecting them to be taken by private individuals. Decisions such as these should be reserved to the public authorities who are responsible for the public good. It follows that both the teaching of science and the conduct of research must be controlled by the state.

I believe this reasoning to be fallacious and its conclusions to be wrong. Yet I shall not try to meet the argument point by point but will instead oppose it as a whole by analysing the actual state of affairs which it profoundly misrepresents. I shall survey the individuals and groups who normally take the decisions which contribute to the growth and dissemination of science. I shall show that the individual scientist, the body of scientists and the general public each play their part and that this distribution of functions is inherent in the process of scientific development, so that none of these functions can be delegated to a superior authority. I shall argue that any attempt to do this could only result in the distortion—and if persisted in—in the complete destruction of science. I shall demonstrate instances where such attempts have actually been made and the destruction did actually come to pass.

II

The primary decisions in the shaping of scientific progress are made by individual investigators when they embark on a

particular line of enquiry. To-day in science the independent investigator is usually a professional scientist, appointed by public authorities in view of his scientific record, to a post where he is expected to do research. For this he is given freedom to use his own time and is often also given control over considerable means in money and personnel.

The granting of such discretion to individuals for the purposes of their profession is fairly common in all departments of life. Holders of higher posts in Business, Politics, the Law, Medicine, the Army, the Church, are all invested with powers which enable them to follow their own intuitive judgment within the framework of certain rules. They use this freedom in order to discharge their duties. Yet the degree of independence granted to the scientist may appear to be greater than that allowed to other professional men. A businessman's duty is to make profits, a judge's to find the law, a general's to defeat the enemy ; while in each case the choice of the specific means for fulfilling their task is left to the judgment of the person in charge, yet the standards of success are laid down for them from outside. For the scientist this may not hold quite to the same extent. It is part of his commission to revise and renew by pioneer achievements the very standards by which his work is to be judged. He may be denied full recognition for a considerable time—and yet his claims may be ultimately vindicated. But the difference is only one of degree. All standards of professional success undergo some change in the course of professional practice, and on the other hand even the most daring pioneer in science accepts the general conceptions of scientific achievement and bases his scientific claims essentially on traditional standards. I shall have more to say in this connection later.

In any case the powers to use his own intuitive judgment and the encouragement to embark on original lines of enquiry are not given to the scientist to enable him to exercise his own personal wishes. The high degree of independence that he enjoys is granted only to enable him to discharge the more effectively his professional obligations. His task is to discover the opportunities in the given state of science for the most successful application of his own talents and to devote himself to the exploitation of these openings. The wider his freedom,

the more fully can he throw the force of his personal conviction into the attack on his own problem.

At the start his task is yet hidden, but it is none the less definite. There is ample evidence to show that at any particular moment the next possibilities of discovery in science are few. The next step to be taken in any particular field is in fact sometimes so clear that we read of a " dramatic race " between leading scientists for an impending discovery. A series of such races took place within a period of a few years for the discovery of the synthesis of various vitamins. In 1935 Karrer in Zürich and Kuhn in Heidelberg competed in the synthesis of Vitamin B2. In 1936 three teams, Andersag and Westphal in Germany, Williams and Cline in the United States and Todd and Bergel in England raced for the synthesis of Vitamin B1. And in 1938 one of the participants in the B1 race, Todd, and one in the B2 race, Karrer, rivalled closely in the synthesis of Vitamin E. Only a few years earlier (1930) a great race was won in physics when Cockcroft and Walton working under Rutherford's guidance in Cambridge accomplished the artificial disintegration of the atom by electric discharge -ahead of Lange and Brasch in Germany and Breit, Tuve, Hafstad, Lauritsen, Lawrence and others in America. Or to take an example in pure theoretical physics: between 1920 and 1925 the standing problem of theoretical physicists was the reconciliation of classical mechanics and quantum theory; and around the year 1925 a number of physicists (de Broglie, Heisenberg, Born, Schrödinger, Dirac) did actually discover - more or less independently—the various parts of the solution. In a review of Eve's biography of Rutherford, Sir Charles Darwin[1] estimates roughly by how much Rutherford may have anticipated his contemporaries with his various discoveries and suggests for most cases spans of time ranging from a few months to three or four years. Rutherford himself is quoted as saying that no one can see more than an eighth of an inch beyond his nose and that only a great man can look even as far as that.

Scientific research is not less creative and not less independent, because at any particular time only a few discoveries are possible.

[1] *NATURE*, 3670, Vol. 145, p. 324, 2nd March, 1940.

We do not think less of the genius of Columbus because there was only one New World on this planet for him to discover.

Though the task is definite enough, the solution is none the less intuitive. It is essential to start in science with the right guess about the direction of further progress. The whole career of a scientist usually remains linked to the development of the single subject which stimulated the early guess. All the time the scientist is constantly collecting, developing and revising a set of half-conscious surmises, an assortment of private clues, which are his confidential guides to the mastery of his subject.

This loose system of intuitions cannot be formulated in definite terms. It represents a personal outlook which can be transmitted only—and only very imperfectly—to personal collaborators who can watch its daily application for a year or two to the current problems of the laboratory. This outlook is as much emotional as it is intellectual. The expectations which it entertains are not mere idle guesses but active hopes filled with enthusiasm.

The emotions of the scientist also express and uphold the values guiding research; they turn with admiration to courage and reliability and pour scorn on the commonplace and the fanciful. Such emotions again can be transmitted only by direct contact in the course of active collaboration. They are in fact the very life-blood of collaboration in a research school Its leader has no more important function than to maintain enthusiasm for research among his students and instil in them the love of his own particular field.

Such is the calling of the scientist. The state of knowledge and the existing standards of science define the range within which he must find his task. He has to guess in which field and to what new problem his own special gifts can be most fruitfully applied. At this stage his gifts are still undisclosed, the problem is yet obscure. There is in him a hidden key capable of opening a hidden lock. There is only one force which can reveal both key and lock and bring the two together: the creative urge which is inherent in the faculties of man and which guides them instinctively to the opportunities for their manifestation. The world outside can help by teaching, encouragement and criticism, but all the essential decisions leading to discovery remain personal

and intuitive. No one with the least experience of a higher art or of any function requiring higher judgment could conceive it to be possible that decisions such as these could be taken by one person for another. Decisions of this kind can in fact only be suppressed by the attempt to transfer them to an outside authority.

IV.

The scientist to-day cannot practise his calling in isolation. He must occupy a definite position within a framework of institutions. A chemist becomes a member of the chemical profession; and a zoologist, a mathematician or a psychologist, each belongs to a particular group of specialised scientists. The different groups of scientists together form the scientific community.

The opinion of this community exercises a profound influence on the course of every individual investigation. Broadly speaking, while the choice of subjects and the actual conduct of research is entirely the responsibility of the individual scientists, the recognition of claims to discoveries is under the jurisdiction of scientific opinion expressed by scientists as a body. Scientific opinion exercises its power largely informally but partly also by the use of an organised machinery. At any particular time only a certain range of subjects is deemed by this opinion to be profitable for scientific work. Accordingly no training is given and no posts either for teaching or for research are offered outside these fields, while existing research schools are specialised in these subjects and so are the journals available for publication.

Even within the fields that are recognised in this sense at any particular time, scientific papers cannot be published without preliminary approval by two or three independent referees, called in as advisers by the editor of the journal. The referees express an opinion particularly on two points: whether the claims of the paper are sufficiently well substantiated and whether it possesses a sufficient degree of scientific interest to be worth publishing. Both characteristics are assessed by conventional standards which in fact are changed from time to time according to variations of scientific opinion. Sometimes it may be felt that the tendency among authors is towards too much speculation which the referees will then try to correct by imposing more

discipline. At other times there may seem to be a danger of absorption in mere mechanical work, which referees will again try to curb by insisting that papers should show more originality. Naturally, at different periods there are also marked variations as regards the conclusions that are considered sufficiently plausible. A few years ago there was a period in which it was easy to get a paper printed claiming the transformation of chemical elements by ordinary laboratory processes ; to-day—as in earlier times—this would be found difficult, if not altogether impossible.

The referees advising scientific journals may also encourage those lines of research which they consider to be particularly promising, whilst discouraging other lines of which they have a low opinion. The dominant powers in this respect are however exercised by referees advising on scientific appointments, on the allocation of special subsidies and on the award of distinctions. Advice on these points, which often involve major issues of the policy of science, is usually asked from and tendered by a small number of senior scientists who are universally recognised as being the most eminent in a particular branch. They are the chief Influentials, the unofficial governors of the scientific community. By their advice they can either delay or accelerate the growth of a new line of research. New facilities for work can be most rapidly made available by the granting at their command of special subsidies for research. By the award of prizes and of other distinctions they can invest a promising pioneer almost overnight with a position of authority and independence More slowly, but no less effectively, a new development can be stimulated by the policy pursued by the Influentials in advising on new appointments. Within 10 years or so a new line of thought may be established by the selection of appropriate candidates for Chairs, which have fallen vacant during that period. The same end can be promoted by the setting up of new Chairs, which sometimes replace others which have become obsolete.

The constant re-direction of scientific interest by the leaders of scientific opinion fulfils the important function of keeping the standards of performance in different branches of science approximately at an equal level. In the various branches the standards of reliability and systematic interest are applied in somewhat different ways. In general, the greater the human interest of

the subject matter, the less rigorous the tests required for establishing the same standard. Living beings are intrinsically more interesting than inanimate nature. Scientific statements will be allowed to be less definite and less certain if made about plants or animals than about minerals or stars. Similarly a speculative achievement of modest range may be recognised as a success if it relates to the problems of living matter. The leaders of scientific opinion have to adjust the different standards in such a manner as to maintain in every field a uniform level of development. This level being jointly characterised by the intrinsic interest of the subject matter, the profundity or systematic interest of the generalisations involved and the precision and certainty of the new statements made.

The steady equalisation of standards in all branches is necessary, not only in order to maintain a rational distribution of resources and recruits for research schools throughout the field of science, but also in order to uphold equally in every branch the authority of science with regard to the general public. With the relation of science and the public I shall presently deal in some detail. But a particular aspect of it requires mention at this stage since it involves the final phase of the process by which recognition is given to new scientific claims. Published papers are open to discussion and their results may remain controversial for some time. But scientific controversies are usually settled—or else shelved to await further evidence—within a reasonable time. The results then pass over into textbooks for universities and schools and become part of generally accepted opinion. We note that this final process of codification is again under the control of the body of the scientific opinion—expressed by reviewers—under whose authority text-books are in fact brought into circulation.

The standards of science—like those of all other arts and professions—are transmitted largely by tradition. Science in the modern sense originated some 300 years ago from the work of a small number of pioneers, among whom Vesalius and Galileo, Boyle, Harvey and Newton were pre-eminent. The founders of modern science have discussed extensively and with considerable insight the new methods which they applied; moreover the doctrines of the contemporary philosophy—particularly

through John Locke—gave full expression to their outlook. Yet the core of the scientific method lies in the practical example of its works. Whatever the various philosophies of the scientific method may still reveal, modern science must continue to be defined as the search for truth on the lines set by the examples of Galileo and his contemporaries. No pioneer of science, however revolutionary—neither Pasteur, Darwin, Freud nor Einstein—has denied the validity of that tradition nor even relaxed it in the least. The great succession of men of genius to whose creative powers science has given scope since the end of the sixteenth century, has not overshadowed the first pioneers but has—on the contrary—increasingly revealed the implications of their discoveries and thus added ever more brilliance to their achievements.

Modern science is a local tradition and is not easily transmitted from one place to another. Countries such as Australia, New Zealand, South Africa, Argentina, Brazil, Egypt, Mexico, have built great modern cities with spacious universities, but they have rarely succeeded in founding important schools of research. The total current scientific production of these countries before the war was still less than the single contributions of either Denmark, Sweden or Holland. Those who have visited the parts of the world where scientific life is just beginning know of the backbreaking struggle that the lack of scientific tradition imposes on the pioneers. Here research work stagnates for lack of stimulus, there it runs wild in the absence of any proper directive influence. Unsound reputations grow like mushrooms: based on nothing but commonplace achievements, or even on mere empty boasts. Politics and business play havoc with appointments and the granting of subsidies for research. However rich the fund of local genius may be, such environment will fail to bring it to fruition. In the early phase in question New Zealand loses its Rutherford, Australia its Alexander and its Bragg, and such losses retard further the growth of science in a new country. Rarely, if ever, was the final acclimatisation of science outside Europe achieved until the Government of the country overseas succeeded in inducing a few scientists belonging to some traditional centre, to settle down in their territory and allowed the newcomers to develop there a new home of scientific

life moulded by their own standards. This demonstrates perhaps most vividly the fact that science as a whole is based in the same way as the practice of any single research school—on a local tradition, consisting of a fund of intuitive approaches and emotional values which can only be transmitted from one generation to the other through the medium of personal collaboration.

Scientific research, in short, is an art; it is the art of making certain kinds of discoveries. The scientific profession as a whole has the function of cultivating that art by transmitting and developing the tradition of its practice. The value which we attribute to science, whether its progress be considered good, bad or indifferent from a chosen point of view, does not matter here. Whatever that value may be it still remains true that the tradition of science as an art can be handed on only by those practising the art. There cannot therefore be any question of another authority replacing scientific opinion for the purposes of this function, and any attempt to do so can result only in a clumsy distortion and, if persistently applied, in the more or less complete destruction of the tradition of science.

V

Professional scientists form a very small minority in the community, perhaps one in ten thousand. The ideas and opinions of so small a group can be of importance only by virtue of the response which they evoke from the general public. This response is indispensable to science, which depends on it for money to pay the costs of research and for recruits to replenish the ranks of the profession. Clearly science can continue to exist on the modern scale only so long as the authority that it claims is accepted by large groups of the public.

Why do people decide to accept science as valid? Can they not see the limitations of scientific demonstrations—in the pre-selected evidence, the pre-conceived theories, the always basically deficient documentation? They may see these shortcomings, or at least they may be made to see them. The fact remains that they must make up their minds about their material surroundings in one way or another. Men must form ideas about the material universe and must achieve definite convictions on

the subject. No part of the human race has ever been known to exist without a system of such convictions and it is clear that their elimination must mean intellectual death. Without them man falls to the level of the beast as regards both the state of his mind and the level of his technical achievements. That must remain out of the question. The choice therefore open to the public is only that of believing in science or else in some rival explanation of nature, such as that offered by Aristotle, The Bible, Astrology or Christian Science. Of these alternatives the public of our times has in its majority chosen science ; and it is the basis of this choice that concerns us here.

Historically, the origin of the decision is not difficult to trace. There were two main battles, one that opened in the sixteenth century against Aristotelian mechanics and astrology and another that opened in the nineteenth century against the cosmology of the Bible. Both of these led to long-drawn campaigns in which the ideas of science spread rapidly generation by generation, and finally extended their influence over all the peoples led by the West.

How was this result achieved ? It was favoured in the first instance by the whole movement of the Renaissance, which aroused independent judgment among educated people. This awakening weakened the forces opposing the dissemination of science. In these circumstances the convincing power of science proved greater than that of its rival. When Galileo demonstrated that objects of widely different weights, when dropped simultaneously from the tower of Pisa, all reached the ground at the same moment, this proved to every witness of the experiment that Aristotle was wrong in teaching that such bodies fall at different rates proportional to their weights. These practical tests were of the same kind as those used by people engaged in the various crafts of mining, building, and in the arts of war ; people willing to think for themselves could not fail to be impressed by them. Though scientific proof was not completely accessible to the layman, what he could be shown proved much more convincing to him than the rival arguments based on Aristotle, the Church Fathers, Astrology or the Bible ; and this has continued to hold to this very day.

This does not mean that the victory of science is either complete or final. Pockets of anti-scientific views persist in various

forms. Scientific medicine is rejected by that part of the public in Western countries which professes Christian Science. Fundamentalism challenges geology and evolution. Astrology has a more or less vague ascendancy in wide circles. Spiritualism carries on a borderline existence between science and mysticism. These persistent centres of heterodoxy are a constant challenge to science. It is not inconceivable that from one of these there may emerge in the future some element of truth inaccessible to the scientific method, which may form the starting point of a new interpretation of nature. In any case at present these anti-scientific movements constitute an effective check on the popular acceptance of science: the failure of their efforts to spread their doctrines, shows that science remains considerably more convincing than any other of the possible alternatives.

So long as this is the case, science could be discredited with the public only by stopping the channels through which it is disseminated and by suppressing at the same time the desire of people to think for themselves. There may be reasons—which may even conceivably be good ones—for doing these things: but the result could obviously be considered only as a distortion or suppression, not as a re-direction of the appreciation of science by the people.

VI.

I have shown that the forces contributing to the growth and dissemination of science operate in three stages. The individual scientists take the initiative in choosing their problems and conducting their investigations; the body of scientists controls each of its members by imposing the standards of science; and finally the people decide in public discussion whether or not to accept science as the true explanation of nature. At each stage a human will operates. But the exercise of will is fully determined on each occasion by the responsibility inherent in the action; and hence any attempt to direct these actions from outside must inevitably distort or destroy their proper meaning.

There are two recent instances on record of attempts made to break the autonomy of scientific life and to subordinate it to State direction. The one made by National Socialist Germany is so crude and cynical that its purely destructive nature is easily

demonstrated. Take the following utterances credibly attributed to Himmler, in which he reproves German scholars who refused to accept as genuine a forged document concerning German pre-history : –

> "We don't care a hoot whether this or something else was the real truth about the pre-history of the German tribes. Science proceeds from hypotheses that change every year or two. So there's no earthly reason why the party should not lay down a particular hypothesis as the starting-point, even if it runs counter to current scientific opinion The one and only thing that matters to us, and the thing these people are paid for by the State, is to have ideas of history that strengthen our people in their necessary national pride."[1]

Clearly Himmler only pretends here – as a mere form of words – that he wishes to readjust the foundations of science ; his actual purpose is to suppress free enquiry in order to consolidate a particular falsehood which he considers useful. The philosophical difficulties in the position of science are mentioned only in order to confuse the issue and to cloak—however thinly –an act of sheer violence.

VII.

The attempts of the Soviet Government to start a new kind of science are on an altogether different level. They represent a genuine effort to run science for the public good and they provide therefore a proper test of the principles involved in such an attempt.

We will illustrate the process and its results by the example of genetics and plant-breeding, to which governmental direction was applied with particular energy. The intervention of the State in these fields began about the year 1930 and was definitely established by the All Union Conference on the Planning of Genetics and Selection held in Leningrad in 1932. Up to that time genetics had developed and flourished in Russia as a free science, guided by the standards that were recognised in other countries, throughout the scientific world. The Conference of 1932 decided that genetics and plant-breeding should

[1]Rauschnigg, *Hitler Speaks*, p. 224-5.

henceforth be conducted with a view to obtaining immediate practical results and on lines conforming to the official doctrine of dialectical materialism, research being directed by the State.[1]

No sooner had these blows been delivered against the authority of science than the inevitable consequences set in. Any person claiming a discovery in genetics and plant-breeding could henceforth appeal directly over the heads of scientists to gullible practitioners or to politically minded officials. Spurious observations and fallacious theories advanced by dilettants, cranks and impostors could now gain currency, unchecked by scientific criticism.

An important case of this kind was that of I. V. Michourin, (1855-1935) a plant-breeding farmer, who some years earlier had announced the discovery of new strains of plants produced by grafting. He claimed to have achieved revolutionary improvements in agriculture, and to have obtained a striking confirmation of dialectical materialism. The opinion of science on the contrary was—and still remains—that Michourin's observations were mere illusions, that they referred to a spurious phenomenon, known by the name of "vegetative hybridisation" which had been frequently described before. The illusion can arise from an incomplete statistical analysis of the results obtained and may be occasionally supported also by the fact that viruses are transmitted to the graft and its offsprings. The occurrence of true hereditary hybridisation by grafting would be incompatible with the very foundations of modern biological science and its existence had definitely been discredited by the formulation of Mendel's laws and the discoveries of cytogenetics.

The denial of Michourin's claims by scientific opinion now lost its force. His work appealed to the practitioner and it conformed to the philosophy imposed by the State. It thus fulfilled both the criteria which had replaced the standards of science. Hence—inevitably—Michourin's work was now given

[1] The Communist Academy, founded in 1926, which had originally been entrusted with the direction of science in the light of Dialectal Materialism had gained no ascendancy over the research work of non-party scientists. The inauguration of the policy described in the text coincided with the dissolution of the Scientific Section of the Communist Academy and represented a replacement of its functions by a more general if much less extreme application of the principles of Dialectal Materialism.

official recognition. The Government, in its enthusiasm over this first fruit of its new policy in science, went even further and erected a monument of unparalleled splendour to Michourin. It re-named the town of Koslov and called it "Michourinsk" (1932)

The breach thus made in the autonomy of science laid the field of genetics and plant-breeding wide open to further invasion by spurious claims. The leader of this invasion became T. D Lysenko—a successful worker in agricultural technique—who expanded Michourin's claims into a new theory of heredity which he opposed to Mendelism and cytogenetics His popular influence caused hundreds of people without proper scientific training, such as farmers and young students of agriculture, to attempt grafting experiments with the aim of producing "vegetative hybrids." Lysenko has himself described proudly how by the labours of this mass movement vegetative hybrids "poured out like the fruits from the horn of abundance"[1] Aided by claims of this kind, Lysenko gained high recognition for himself by the Government. He was appointed a member of the Academy of the U.S.S.R. and made President of the Academy of Agricultural Science of the U.S.S.R. By 1939 his influence had reached the point that he could induce the Commissariat of Agriculture to prohibit the methods hitherto used in plant-breeding stations and to introduce, compulsorily, new ones that were based on his own doctrine of heredity and that were contrary to accepted scientific opinion.[2] In a publication of the same year he even went so far as to demand the final elimination of his scientific opponents, by the total abolition of genetics in Russia : "In my opinion"—he wrote—"it is quite time to remove Mendelism entirely from University courses and from the theoretical and practical guidance of seed-raising."[3]

However, the Government hesitated to take the decisive step and a conference was called to clarify the situation. The Editors of the Journal "Under the Banner of Marxism" acted as conveners, and the proceedings, together with an extensive

[1] Lysenko's speech at the Conference on Genetics and Selection, Moscow, 1939, quoted in the following as C.G.S. 1939.

[2] Vavilov's speech, C.G.S. 1939.

[3] Quoted by N. P. Doubinin in his speech at the C.G.S. 1939, from Lysenko "The Mentor an all powerful tool in selection" p. 38, 1939.

editorial commentary, were subsequently published in that Journal.[1] The reports of this Conference form impressive evidence of the rapid and radical destruction of a branch of science caused clearly by the fact that the conduct of research had been placed under the direction of the State. We may note that the government in this case was a particularly progressive one and that it was aiming at solid reasonable benefits for its own people. It is all the more significant that in spite of this, the result of its action was only to plunge the science of genetics into a morass of corruption and confusion.

The Conference, which revealed these conditions to the outside observer was presided over by M. B. Mitin (a person unknown to international science and probably a representative of the Journal), who in his opening speech outlined once again what the practical and theoretical principles were to which science must conform when under the direction of the Soviet State. "We have no gulf between theory and practice, we have no Chinese wall between scientific achievements and practical activity. Every genuine discovery, every genuine scientific achievement is with us translated into practice, enters into the life of hundreds of institutions, attracts the attention of the mass of people by its fruitful results. Soviet biologists, geneticists and selectionists must understand dialectic and historical materialism, and learn to apply the dialectic method to their scientific work. Verbal, formal acceptance of dialectical materialism is not wanted."

Academician N. I. Vavilov, internationally recognised as the most eminent geneticist in Russia (as shown by his recent election as Foreign Member of the Royal Society) put the case for the science of genetics. He surveyed the development of this science from its inception and pointed out that not a single author of repute anywhere outside Russia would either doubt the soundness of cytogenetics, or would be prepared to accept the existence of so-called "vegetative hybrids."

Such appeals however had now become groundless ; with the establishment of State supremacy over science, the authority of international scientific opinion had been rendered void.

[1]Translated extracts from the Conference Report were available by courtesy of the Society for Cultural Relations with the U.S.S.R. The translation was checked and revised by reference to the original text.

Vavilov was rightly answered by being confronted with his own declaration made at the Planning Conference of 1932 in which he had deprecated the cultivation of science for its own purposes. Yielding at the time perhaps to pressure, or believing it wise to meet popular tendencies half way, little expecting in any case the far reaching consequences to follow from his relinquishment of principles—he had then allowed himself to say: "The divorce of genetics from practical selection, which characterises the research work of the U.S.A., England and other countries, must be resolutely removed from genetics-selection research in the U.S.S.R."[1]

Such principles having now been generally accepted, Vavilov could raise no legitimate objection if the classical experiments to which he referred, and on which his branch of science was based, were laughed to scorn by men like the practical plant breeder V. K. Morozov— who addressed the meeting as follows: "The representatives of formal genetics say that they get good 3:1 ratio results with Drosophila. Their work with this object is very profitable to them, because the affair, as one might say, is irresponsible . . . if the flies die, they are not penalised." In Morozov's opinion a science which in 20 years had produced no important practical results at his plant breeding station, could not possibly be sound.[2]

This view can in fact be considered as a correct conclusion from the criteria of science now officially accepted (though fortunately by no means universally enforced) in the Soviet Union. If all the evidence drawn from practically unimportant cases is to be disregarded or at least treated lightly, then little proof can remain in support of the theories of genetics. In such circumstances any simple, plausible ideas such as the fallacies advocated by Lysenko must inevitably acquire the greater convincing power and gain the wider support among all non-specialists, whether practitioners or ordinary laymen. This is in fact what the Conference on Genetics demonstrated. Morozov could assure

[1]Proceedings of the All-Union Conference on planning Genetics-Selection research, Leningrad, June 29th, 1932, p. 21 Academy of Science of U.S.S.R., Leningrad, 1933, quoted by Lysenko in his speech at C.G.S. 1939.

[2]Morozov's speech, C.G.S. 1939.

Lysenko that nearly all practical field workers, agronomists and collective farmers had become followers of his doctrine of heredity.

The authority of science having been replaced by that of the State, it was also logical that political arguments should be used against Vavilov's traditional scientific reasoning. Lysenko for example introduced such arguments as follows: "N. I. Vavilov knows that one cannot defend Mendelism before Soviet readers by writing down its foundation, by recounting what it consists of. It has become particularly impossible nowadays when millions of people possess such a mighty theoretical weapon as 'The short Course of the History of the All-Union Communist Party (Bolshevists).' When he grasps Bolshevism, the reader will not be able to give his sympathy to metaphysics, and Mendelism definitely is pure, undisguised metaphysics "[1]

It was logical again that Lysenko and his adherents should invoke Michourin as an authority whose claims had been established by the State; that Lysenko should speak of "that genius of biology I. V. Michourin, recognised by the Party and the Government and by the country . . ." and declare that it is "false and conceited" on the part of a biologist to think that he could add anything to Michourin's teaching.

In such circumstances there seems indeed nothing left to the hard pressed scientists but to attempt a defence in the same terms as used by their opponents. This is what the eminent geneticist Professor N. P. Doubinin apparently decided to do at the Conference on Genetics. His speech in defence of cytogenetics refers freely to Marx, Engels and the "Short Course of the History of the Communist Party." He reverently mentions Michourin, naming him as a classic next to Darwin. But in his view—as he explains—all these high authorities are directly or indirectly supporting Mendelism. "It is quite wrong," he says, "to describe Mendelism by saying that its appearance represents a product of the imperialist development of capitalist society. Of course after its appearance Mendelism was perverted by bourgeois scientists. We know well the fact that all science is class science."

[1]This passage is quoted by Lysenko in his speech at C.G.S. 1939, from an article published by himself in *Socialist Agriculture*, February, 1939. In his speech Lysenko reaffirms this statement.

Such is the last stage in the collapse of science. Attackers and defenders are using the same spurious and often fanciful arguments, to enlist for their own side the support of untutored practitioners and of equally untutored politicians.

But the position of the defenders is hopeless. Science cannot be saved on grounds which contradict its own basic principles. The ambitious and unscrupulous figures who rise to power on the tide of a movement against science, do not withdraw when scientists make their last abject surrender. On the contrary they stay to complete their triumph by directing against their yielding opponents the charge of insincerity. Thus Lysenko says, "The Mendelian geneticists keep silent about their own radical disagreement with the theory of development, with the teaching of Michourin," and even more jeeringly is the same taunt made by Lysenko's assistant Professor I. I Prezent: "It is new to find that all of them, some more sincerely than others, all of them try to give the impression that with Michourin at least they have no quarrel."[1]

Such taunts are unanswerable and their implications are shattering. They make it clear that scientists must never hope to save their scientific pursuits by creeping under the cloak of essentially anti-scientific principles. "Verbal, formal acceptance of these principles" the Chairman had sternly warned from the beginning "is not wanted"

VIII.

The demonstration given here of the corruption of a branch of science caused by placing its pursuit under the direction of the State, is, I think, complete. The more so --I wish to repeat – as there is no doubt at all of the unwavering desire of the Soviet Government to advance the progress of science. It has spent large sums on laboratories, on equipment, and on personnel. Yet these subsidies, we have seen, benefited science only so long as they flowed into channels controlled by independent scientific opinion whereas as soon as their allocation was accompanied by attempts at establishing governmental direction they exercised a violently destructive influence.

[1] Quoted by Kolbanovsky in his summary of the C.G.S. 1939.

We may hope and expect that one day the Soviet Government will recognise the error in such attempts. That they will realise, for example, that their plant-breeding stations are operating on lines which were abandoned as fallacious in the rest of the world about forty years earlier.

What can a government do when it realises such a state of affairs? What course can it then take to restore the functions of science?

According to our analysis the answer cannot be in doubt. One thing only is necessary but that is truly indispensable. It is only necessary to restore the independence of scientific opinion To restore fully its powers to maintain scientific standards in respect of all their proper functions, in the selection of papers for publication, in the selection of candidates for scientific posts, in the granting of scientific distinctions and in the award of special research subsidies. To restore to scientific opinion the power to control by its influence the publication of textbooks and popularisations of science as well as the teaching of science in universities and schools. To restore to it above all the power to protect that most precious foothold of originality, that landing ground of all new ideas, the position of the independent scientist- who must again become sole master of his own research work.

There is still time to revive the great scientific tradition of Russia which, although at present distorted in many respects, is very far from being dead. The recent great progress of Russian mathematics, and of many other fields in which State control has never been effectively applied, proves that the valuation of science for its own sake still lives in U.S.S.R. Let scientists be free once more to expound their true ideals. Let them be allowed to appeal to the Soviet peoples; to ask for their support of science on its own grounds, for the understanding and love of science when pursuing its own immortal purpose. Let them be free to expose the cranks and careerists who have infiltrated into their ranks since the inception of "planning" in 1932. Let the Soviet scientists become affiliated again to the body of international science.

The very moment that scientists regain these freedoms, science will flourish again. Overnight it will rise again free of all the

confusion and corruption which is now affecting it ; and, aided by the rich endowments which it is receiving from the State, the Russian scientific genius will once more speed on, unhampered, to new great achievements.

IX.

However, the current of future events may well tend towards the very opposite course. We are experiencing to-day a weakening of the principles of scientific autonomy in countries where science is still free. There is a movement afoot among scientists themselves, urging that science should be adjusted to social ends. " Science must be marshalled for the people " Professor H. Levy is reported to have proclaimed at a popular rally of scientists in London only a few weeks ago. Fired by misguided generosity these scientists would sacrifice science—forgetting that it is theirs only on trust for the purpose of cultivation, not theirs to give away and allow to perish.

Our analysis seems to leave no doubt, that if this kind of movement prevailed and developed further : if attempts to suppress the autonomy of science, such as have been made in Russia since 1932, became world wide and were persisted in for a time, the result could only be a total destruction of science and of scientific life. Single individuals could perhaps continue to study pure science and to achieve sporadic progress as some did even during the Middle Ages. But the swift and steady progress of discovery, as experienced in the past 100 years, would be brought to a standstill and presently the main body of science itself would disintegrate and fall into oblivion.

That is why we must recognise the essentially autonomous nature of science with all its great implications.

New Greek Vases in Manchester.

By Professor T B L Webster M A , F S A

1 *Black-figured cup* (pl I *a* and *b*)[1]

This cup was bought at Spinks in August 1942 The foot may or may not belong but is at least contemporary All restoration has been removed The cup is in the normal black figure technique red is added for centre and alternate petals of handle palmettes, alternate tail feathers and spots on wing of left-hand hen curling tail feathers base of wing feathers neck comb and wattles of cocks neck and wing of right hand hen neck ribs hind-quarter stripes of deer hair fillet hair-band wings and tail stripe of siren white was added for head and neck and dots in tail feathers of left-hand hen wing stripes of cocks (probably also wing stripe of right-hand hen) faces and breast of sirens

Professor Beazley recognised the hand of the Tleson painter in this cup Subject is identical in an unsigned band cup of the Loeb Collection (*JHS* lii pl ix) and another in the Cabinet des Médailles (*C V* pl 47 5-6) identical details are the use of red and white on wings and tails of cocks and hens and the drawing of the cocks' tail feathers and neck feathers But the Loeb and Paris cups are coarser though perhaps more spirited note on both the sirens and palmettes as well as the cocks and hens The Paris stag has identical markings but a shorter, thinner body and a smaller, fatter head (cf New York *Metr Mus Bull* 33 53) The cock (*JHS* lii 173 fig 5) on a signed lip cup in Castle Ashby has the slim delicacy that our cocks would have if not inflated for battle similar cocks appear on other lip cups signed by Tleson (Hoppin, *Bf* , no 2 *Metr Mus Bull* 33, 53) The twin of our right-hand hen is on a Berlin cup (Hoppin, *Bf* , no 1, cf no 26)

The attribution to the Tleson painter is beyond all doubt and our cup adds one to his small number of Band-Cups (another is in the Manchester School of Art —Herford, *Handbook*, pl 6b *Manchester Memoirs*, 78, 1) , but the sharp-beaked hen on the left, the siren with wig hair and folded wings, the careful handle palmettes with separate petals are not seen again among his published cups The sharp-faced siren looks earlier than any

[1] I am indebted to Professor W H Lang for the photographs reproduced as pl I and IV

of his sirens so do the careful palmettes It seems therefore justifiable to date the cup rather before 550 B C

The cocks and hens are a farmyard scene the other side is reminiscent of the animal friezes so common on vases of the late seventh or early sixth centuries (cf *Manchester Memoirs*, 83, pl I)

2 *Black figured hydria* (pl II)

This vase was purchased from Spink in August 1942 its previous history is unknown It is in the black-figure technique red is added for alternate tongues beneath the neck in shoulder scene for mantle strip of left-hand figure comb of helmet and spots inside shield of left hand warrior chiton skirt of escaping warrior shield rim of rescuing warrior himation strips of right hand figure in main scene inside of himation dots on outside of himation of charioteer basket of chariot tails manes and gerths of horses crest holder and helmet band of warrior hair fillet, pupil, and himation folds of woman and in the predella for wing strip of siren the main scene is bounded by two red bands at the bottom and a red band crowns the rays round the base Added white is used on the shoulder for five-dot rosettes on the himation of the left-hand figure for the baldric and arm-band of the left-hand warrior's shield for the tripod charge of the escaping warrior's shield, for the helmet crest baldric and charge of the rescuing warrior, and for five-dot rosettes on the right-hand spectator in the main picture for hair fillet and dot rosettes on the himation of the charioteer, for hair, beard, dots round the top and bottom edges and dot rosettes on the swallow-tail of the old man's himation, dot rosettes on the himation of the warrior triple dots below the horse's gerths, dots between the incised crosses of the woman's chiton, and for her face, hands, and feet, and in the predella for dot rosettes on the himation of the two young men and on the narrow band below the red strip of the siren's wings The vase has a graffito on the foot

When the red was bright and the white was white instead of, as now, being merely a dirty mark on the black glaze, the vase was a gay vase, and this as well as the style connects it with a group of vases "in the manner of the Andokides painter"

Two vases are worth comparison an amphora in Wurzburg (Langlotz 267, pl 76-7) and a hydria in London (B 339 C.V A pls 92, 95) The first striking link between the three vases is the shape of the horses slim-bodied, narrow-necked, small-headed, fiery-mouthed Even in the inadequate picture of the London vase the white pendants attached to the horses' gerths can be seen in the much better picture of the Wurzburg vase details of heads, bodies and legs can be seen to be identical The predella of the London vase has a siren shaped like the Manchester siren the fight on the shoulder is similarly framed by young men Details of the human figures on the Wurzburg vase clinch the matter, knees of the fluting satyr with those of the warrior behind the horses, treatment of folds, but especially the red blobs, white dot rosettes, white dot borders, and white dots in the angles of incised crosses that ornament the clothes

The painter worked "in the manner of the Andokides painter" (see Beazley, *Attic Red-figure Vase-painters*, 4) The Andokides painter was the pupil of the great black-figure painter Exekias and was the first painter to use the new red-figure technique Our vase was painted about 520 B C There is little to be said about the subjects. a soldier son is driven away on his chariot from his father and mother on the shoulder, a fight —on the predella a siren · neither here nor on the London vase has the siren any connection with the charmers of Odysseus, she is a symbol of strength, a monstrous being like the Sphinx, often placed on tombs to keep alive the memory of the dead. Two young Athenians watch the fight and two others watch the siren, linking the to-day world of the painter and his customers with the mythical world of his pictures

3. *Pelike* (pl. IV *a*).

The accompanying photograph gives a detail from a pelike which was in the Collection of Mr. Beatson Blair of Manchester, and previously in the Collection of Mr C W. Curtis. The two pictures represent Eos and Cephalus and two women about a wool basket. The pattern above Eos and Cephalus is a slanting palmette and volute, the pattern above the two women is a laurel wreath. Underneath both pictures is a mæander chain with a cross substituted for every third mæander. The Eos

and Cephalus scene consists of Eos chasing Cephalus, who looks back at her, and a third figure presumably Tithonus, to the left of Eos. Tithonus and Cephalus wear petasoi and cloaks and high-laced sandals: Cephalus carries a spear. The right arm of Tithonus is obscured by overpainting. The winged Eos wears an Attic peplos with a short garment, probably a skin, battlemented and spotted, over her shoulders falling to the hips. Red is used for Eos' hairbands and for the petasos' strings of the two young men. The two women on the back are dressed in chitons with himations over one shoulder. Red is used for their hairbands and for swags of wool at the top of the wool basket. The woman on the left holds a chequered tray or basket: The woman on the right stretches out her hand to take something from the wool basket. The women are going to visit a tomb and are preparing their tray of offerings.

The vase shows very clear traces of the preliminary sketch which was made on the drying clay, partly with a blunt tool and partly with a sharp tool. The preliminary sketches of the naked bodies can be seen underneath their drapery. In certain places the artist has ruthlessly abandoned the guiding lines of the sketch. On the front he has left out the left wing of Eos, of which the outline can clearly be seen running past the edge of the petasos and the nose of the left-hand man. On the back of the vase the painter has reduced the basket to a bare chequered oblong: the incised lines show that the basket flared outwards at both ends and had a rail along the top; it also had a curious striped streamer depending from the left side. Baskets of the same kind can be seen on the white lekythoi (*e.g.*, Pfuhl, *M.v.Z.* fig. 529, 540, 551), although the exceptionally broad streamer is perhaps unique. The preliminary sketch also shows a quite different outline of the left woman's leg.

The scheme of the Pursuit of Cephalus is the same as on the Leyden neck amphora of the Niobid painter (Webster, *Niobidenmaler*, 12) and on the later Baltimore bell crater by the Christie painter (*C.V.A.* Baltimore, fasc. 2, pl. 45), but on our vase the figures stand out independently against the background and there are no overlapping feet as on the other two representations, nor does Eos dwarf the mortals as on the Baltimore vase.

The artist of our vase must be sought among the companions of Polygnotus. It is a careless work but reflects something of his classical style. In detail it is worth comparing the profile eye with the profile eye of the woman on the right of the Baltimore hydria (*loc. cit.* pl. 44) or with the more elaborate eyes of the horsemen on the craters in Oxford (*C.V.A.* Oxford, fasc. i, p XXIX-XXX). The high-laced sandals also recur on the Oxford craters. The Leyden vase by the Niobid painter is an earlier work · a later vase, probably a school piece, in Rhodes (*C.V.A.* Rodi, iii, i.c. pl 4) points forward to our vase, which will have been made about the middle of the century by a companion of Polygnotus who continued but softened the Niobid painter's tradition.

4. *Oenochoe* (pl. I*c*, III).

This oenochoe was purchased from Messrs. Spink in June, 1942. The underneath of the jug is reserved and there is no trace of graffito or dipinto. The figures stand on a base line over a rough egg and tongue ornament. There are three figures: a youth reclines on a couch in the centre; the cushion at the head of the couch and the rug round his legs are painted in white which has to a large extent flaked off: white is similarly used for the chiton of one of the goddesses on a crater in Vienna (Hahland, *Vasen um Meidias*, pl. 18): a small end of the rug hangs over the side of the couch below the youth's left hip as on the Dinos painter's Palermo fragment and on other vases of the time (Hahland, *Vasen um Meidias*, pl. 5, pl. 12a). A second youth comes up from the left with a wine jug in his right hand and a cloak somewhat precariously balanced over his left arm. A third, a bearded man, comes up from the right with a large (water ?) jug poised in his left hand and a cloak hung over both arms and falling behind his back; he wears shoes. All the men have ivy-leaves in their hair.[1]

[1] The painter has not made the interpretation quite clear, but the projections from the head seem to be ivy-leaves rather than a variant of the flame fillets discussed in detail by Professor Smith in the text to *C.V.A.* California, pl. 41b. A rather similar adornment, which must be classed as a flame-fillet, but with the fillet itself much more clearly shown, occurs on a cup in the Mouret Collection (*C.V.A.* France, pl. 234, 1) and on a fragment from Al Mina of about the same date as the oenoche (Beazley, *J.H.S.*, 1939, 27, No. 77). A close parallel can be seen on a bell-crater in Heidelberg (Hahland, *Vasen um Meidias*, pl. 7a).

Traces of the first sketch done with a blunt instrument are visible within the outlines of all the figures, the sketch lines on the couch below the reclining youth's left elbow suggest that in the original scheme a skyphos was to stand on a small table at the youth's side to receive the drink for which he calls The scene then is a youth at a party two friends moving rather unsteadily bring him the materials for a drink their movements are a conscious echo and a tipsy parody of Harmodios and Aristogeiton as they appear on a jug of the same time (Hahland, *Vasen um Meidias*, pl 6a)

The jug may be attributed to the workshop of the Jena painter and stands between the more careful pictures and the careless outsides of the cups in Wurzburg (Langlotz pl 163) and Bonn (*C V A* , pl 10) For the profiles compare particularly the Bonn cup (*C V A* , pl 11 1) and some of the figures on the Enséiune cup (*C V A* Mouret France pl 231) for the treatment of the eyes and of the nipples on the bearded figure compare the satyr of the Wurzburg cup (Langlotz, pl 162) and Dionysus on a cup in the Manchester Whitworth Art Gallery (pl 4*b*) for the treatment of the hair compare particularly the Bonn cup (already quoted), for the two lines below the collar bone compare the Wurzburg satyr (already quoted), for the hands and the drapery compare the rather more carefully painted exterior of the Jena cup (Hahland, *Vasen um Meidias*, pl 16b) The jug is certainly by an artist who is near to the Jena painter and, like him, works in the tradition of the Dinos painter—a strong style of the early fourth century which contrasts with the softer Meidian style (*Manchester Memoirs*, 78, pl 4) and foreshadows the Kertch style

PLATE I[illegible]

PLATE I[illegible]

PLATE Ic.

PLATE 2

PLATE 3

PLATE 4*a*

PLATE 4*b*

Man and the Weather.

By Professor D. Brunt, Sc.D., F.R.S.

It is perhaps not inappropriate to devote a lecture which commemorates the work of Joule to the consideration of the effects on the human body of the physical conditions to which it is subjected. The most important of these conditions are sunshine, temperature, humidity and air movement. All four of these factors have a bearing on the heat balance of the human body, while the ultra-violet rays in sunshine have an important bearing on health. We shall therefore begin by considering briefly the effects of the ultra-violet rays.

The effects of ultra-violet rays.

Of the ultra-violet rays which fall on the skin about 30 % penetrate the corneum or outer horny layer of the epidermis, while only 16 % pass through the lower limit of the epidermis into the true skin below. They produce a number of effects in the skin. In the first place they cause sun erythema or the reddening and blistering of the skin, which only appears after a delay of at least one hour after exposure. It is thus extremely easy to sit too long in sunlight rich in ultra-violet light, since the harm is done without any warning sensation at the time. The erythema lasts from one to three days and is followed by pigmentation of the skin. In these features it differs from ordinary heat burn, which has no period of latency and which disappears soon after the cessation of exposure, leaving no pigmentation. Sensitivity to sunburn is greater in naturally pale-faced persons than in the darker skinned, in men than in women, in middle years of life than in childhood or old age, and in a given individual is less in summer than in winter. The pigmentation of the skin affords subsequent protection against sunburn, the pigment having high absorbing power for ultra-violet rays. Sweat also absorbs ultra-violet light readily, and the skin when sweating is not subject to sunburn.

Snow blindness (solar conjunctivitis) is an effect purely of ultra-violet radiation. But perhaps the most remarkable effect of sunshine rich in ultra-violet light is the transformation of certain constituents of the skin into vitamin D, the anti-rachitic vitamin. Rickets is a disease of the rather sunless regions, and

is quite unknown in the tropics, except in regions where children are brought up under purdah, being kept hidden away indoors for the first year of their lives Rickets is almost unknown at levels of 3,000 feet or more above mean sea level Ultra-violet light also kills bacteria The wavelengths which are effective in burning the skin, in causing snow blindness, in forming vitamin D within the skin, and in killing bacteria all fall within a short range of wave lengths near 0 31μ

The Heat Economy of the Body

For the purpose of this lecture we define man as an intricate heat engine, complicated by the possession of a nervous system This engine works at its greatest efficiency when its internal temperature is a little above 98° F Heat is generated within the body as a result of digestion and of muscular effort, and must be dissipated from the body as rapidly as it is generated if overheating of the body is to be avoided The body can however maintain an approximate balance between production and dissipation of heat over a wide range of external conditions, and a man shivering with cold on a winter's day will have almost the same internal temperature as he will have on a summer's day with sweat dripping from his forehead

The heat generated within is conducted to the skin largely by the blood circulation In a cold environment, the surface blood vessels are constricted, and the skin cooled, so that the loss of heat is minimised In a hot environment, a new factor comes into play, and sweat is secreted by the sweat glands, and in evaporating helps to cool the body Sweat may be described as the body's safety valve in a hot environment

We shall now consider the items in the heat balance, bearing in mind that the skin temperature will usually differ from the internal temperature, and limiting the discussion at first to indoor conditions, where effects of sunshine do not occur

The processes of oxidation of the body tissues, in the course of digestion and of doing work, are grouped under the name of *metabolism*, and the rate at which internal heat is produced in consequence of these processes is known as the metabolic rate Life cannot continue without metabolism, and the more active the life, the greater the metabolic rate Even during sleep there

is a steady generation of heat within the body, and this heat must be removed as fast as it is produced if the body is to retain its normal temperature

The processes of removal are three in number Heat is constantly being lost by evaporation from the skin and from the lungs The air, if colder than the skin will carry away heat from the body by convection and if warmer than the skin will give heat to the body The body loses or gains heat by radiation to and from surrounding objects walls etc according as the skin is warmer or colder than the surrounding objects Further the body may suffer a net loss of heat and become cooler The net loss of heat is called storage If we represent the effective rate of each of the five factors named by the appropriate capital letter, metabolism by M evaporation by E convection by C radiation by R and storage by S then the balance is represented by the equation

$$M + S = E + R + C$$

where R and C are positive when they represent rates of loss of heat to a cooler environment It is by means of this equation that the loss due to radiation and convection is computed the storage being computed from change in body temperature.

Within the last few years there has been accumulated a fair amount of accurate information as to the magnitude of these factors In the subsequent pages we shall use mainly data acquired by a team of American physiologists Winslow, Herrington and Gagge, working at the John B Pierce Laboratory of Hygiene, Newhaven, Conn The subjects were placed in a specially-constructed booth, in which temperature humidity and air movement could be controlled with a high degree of accuracy, while the radiation from the walls could be controlled by special heating or reflecting arrangements in the walls The loss of weight by evaporation was measured by means of a balance sensitive to 2 grammes, say 1/14 ounce

The measurements were usually made on nude subjects Clothing is to be regarded as a complication which tends to mask the essential physiological processes involved Some recent measurements have been made on clothed subjects, the clothing consisting of a two-piece suit of cotton underwear, a

cotton shirt without tie, socks, low leather shoes, and a dark gray two-ply suit with three-quarter lined coat and fully lined vest. A series of measurements on subjects so clothed is represented in fig. 1. In the diagram *M* and *S* are measured positive upwards, while *E* and *R* + *C* are measured positively downward from the zero line. While the temperature of the air ranged from 10° C. to 40° C. (50° F. to 104° F.) metabolism varied little, though there was a definite increase at the lowest temperatures. The temperature which is plotted in the diagram, called operative temperature, is a weighted mean of the temperatures of air and walls, estimated to give a representation of the joint

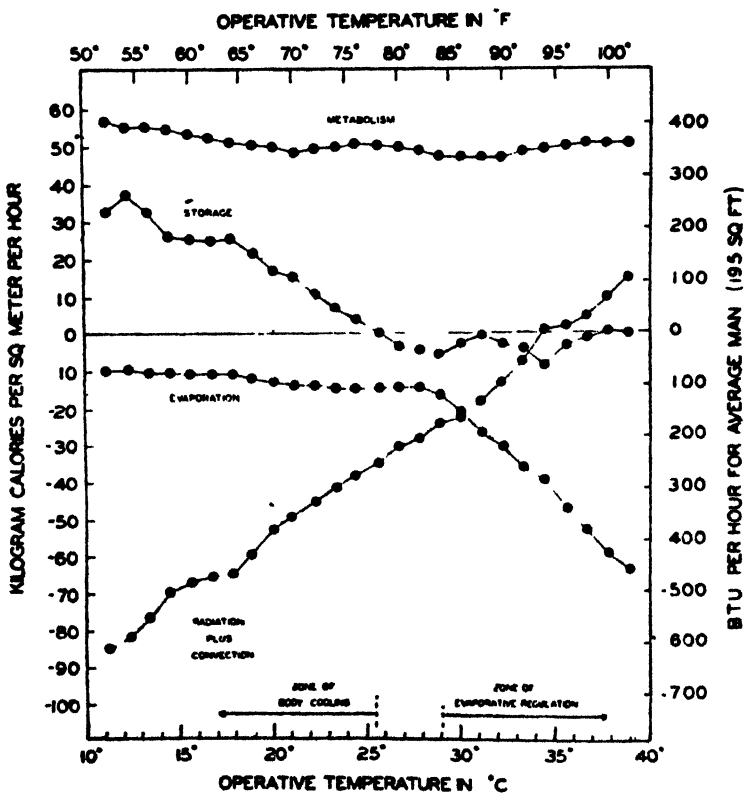

FIG. 1

Relation of metabolism, storage, evaporation and radiation plus convection to operative temperature, for lightly-clothed reclining subjects. (After Winslow, 1941.)

effect of radiation and convection and it is only the sum of these two items which is given in the diagram The vertical scale measures each of the variable items of heat balance in terms of kilogramme calories per square metre per hour, a unit which is equal to about 4 B T U per square metre per hour In subsequent mention of the magnitudes of any of the variables, it is proposed to use the word *unit* to represent 1 kilogramme calorie per square metre per hour in order to avoid repetition of a long description

The loss by evaporation at all operative temperatures below about 29° C is due to the evaporation in the lung passages and to the evaporation of insensible perspiration from the skin In this range of temperatures more than half of the evaporative loss takes place in the respiratory tract and less than half from the skin Above 29° C the evaporation loss rises rapidly with the beginning of active sweat secretion The loss by radiation and convection combined increases as temperature falls and is reversed at high temperatures these processes then helping to warm the body In still conditions radiation accounts for more than half of the joint effect but when air movement increases convection becomes the more important Perhaps the outstanding feature of the diagram is the fact that at low temperatures the essential control over heat loss is exercised by radiation and convection, the evaporative loss remaining nearly constant at a value far less than the metabolic rate while at high temperatures radiation and convection are unimportant or tend to warm the body, and the essential control over heat loss is exercised by evaporation

The graph for storage shows that at temperatures below 25° C the body loses heat (in the zone of body cooling) while at temperatures above 29° C, or 85° F, there is a slight negative storage, or body heating but the evaporative loss checks this storage, and, as we shall see later, maintains the skin temperature at a nearly constant level Temperatures above 29° C belong to what is known as "the zone of evaporative control" The region between 25 and 29° C, in which the heat balance is maintained by the dilation or contraction of the surface blood vessels, without either body cooling or active secretion of sweat, is known as "the zone of vaso-motor control"

In fig. 2 are shown measurements made, on nude subjects, of skin temperature and of several other factors. It is seen that at temperatures below 31° C. the mean skin temperature falls about 1° for every 2° fall of operative temperature, while in the zone of evaporative control, up to 37°, skin temperature remains constant, again increasing slightly at operative temperatures above 37° C. For nude subjects the zone of vaso-motor control is from 27° to 31° C.

The curve marked W is a measure of the wetted area of the skin, and will be discussed in fuller detail later. The wetted

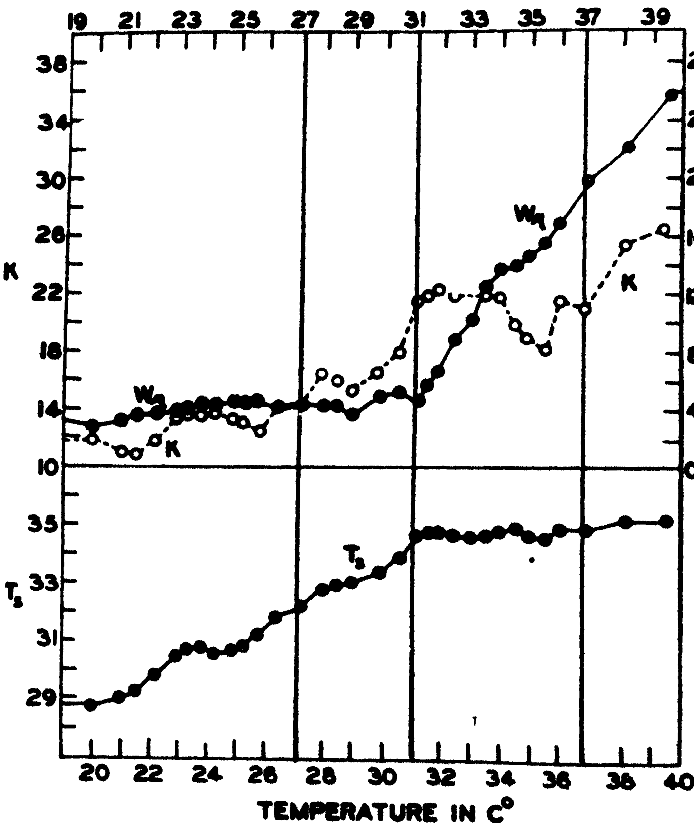

FIG. 2.

Physiological response of nude subjects to varying operative temperatures. W = wetted area K conductance. T_s = mean skin temperature. (After Winslow, 1941.)

area remains substantially constant at all temperatures below 31° C, but rises rapidly as active sweat secretion sets in

The conductance K might be quite simply defined as the power of conduction of heat of the body itself, as shown in the transfer of heat from the inner parts of the body to the skin It is the joint effect of the normal conductive power of the body tissues and of the transport of heat to the skin by the blood stream The conductance is defined as $M + S$ divided by the difference between internal and skin temperatures Its value varies little in the zone of body cooling rises rapidly in the zone of vaso motor control, remains substantially constant in the zone of evaporative control but rises again beyond this zone, when the body strives to get rid of its excess heat by transporting it to the skin Experiments show that the conductance is lower in fat than in lean subjects and is lower in women than in men Women generally have a more considerable layer of subcutaneous fat than men in addition, they have at low temperatures a readier tendency than men to increase their metabolic heat rate For these reasons women are able to bear cold better than men It is a frequently-observed fact that women bear without complaint a degree of cold which men would find trying were they only protected from it by the same amount of clothing The lower conductance of the body in women checks the flow of heat outward to the skin at high air temperatures while men sweat at lower temperatures, and sweat more at high temperatures, than women do Hence, women find heat more trying than men do

A large part of our lives is spent indoors, in conditions of moderate temperatures in which equilibrium of body temperature is maintained by radiative and convective loss from skin or clothing, which has to balance the metabolic production of heat, except for the practically constant amount lost by the evaporation of insensible perspiration The joint radiative and convective loss is determined by (*a*) the difference of temperature between the environment and the body (*b*) the amount of clothing worn, and (*c*) the air movement In cold conditions, when the loss $(R + C)$ is too great, the influence of any one of the three factors can be diminished, for example, we might stir the fire, put on more clothes, or close the window When

the loss ($R + C$) is too low, so that we feel too hot, the reverse action may be taken, and we may allow the fire to burn low, take off some clothing, or open the window.

A rise of body temperature may be produced by increased generation of internal heat, due to increased physical effort either while wearing too much clothing or during exposure to high temperature, indoors or out of doors. It may also arise from the wearing of too much clothing in heated rooms; this was at one time the cause of much ill-health among young children.

The magnitudes of the items in the heat balance of the body.

The items in the heat balance are summarised below. All these items are given in terms of the same unit, the kilogramme calorie per square metre of skin surface per hour, even in discussing those which are not strictly surface phenomena.

M = *metabolic rate.* This is closely proportional to the total area of the skin. It is lowest during sleep, and is increased during active digestion, and by any physical effort. The stimulus to increased metabolic rate becomes marked at temperatures below 14° C. Approximate values are

40 units during sleep (the so-called basic rate).
55-60 units when awake and at rest.
75 units during very light work when standing.
105 units when walking at about 2 m.p.h.
190 units when walking at 4 m.p.h.
300 units when swimming.
400-650 units during strenuous exertion.

H = *gain of heat from radiation from sun and sky.* Averaged over the whole body, this may amount to

Maximum of 360 units at midday with the sun high;
270 units on average summer midday;
180 units on day clouded with fairly high cloud;
zero when sky is overcast with thick low cloud.

If unsuitable clothing is worn, i.e., clothing which absorbs a large fraction of this radiation, this item will be difficult to compensate in summer. Suitable clothing will reflect up to four-fifths of this radiation, but even the remaining fifth will be an important item in the heat balance of the body in still conditions.

R = net gain or loss of heat by radiational interchange between body and environment. In computing this, the body and the ground, walls, etc., may be regarded as capable of radiating the full amount radiated by a black body at the same temperature. The net rate of exchange of heat between the body and the radiating part of the environment (walls, ground, etc.) will be about 2 units per ° F. difference of temperature between body and environment, the body losing or gaining heat according as it is warmer or colder than the environment. The factor, given as 2 in the statement above, increases slightly with increasing temperature, but the value 2 may be taken as a sufficiently close approximation for most purposes.

The figures given above apply to indoor conditions, or to outdoor conditions when the sky is overcast with low cloud. With clear sky, there is an additional item of loss to the sky roughly equal to one-fourth of the total radiation from the ground, amounting to an increased loss of 20-30 units. Thus, on a still hot night in summer, when the sky is clear, it will be appreciably cooler out of doors than indoors, partly on account of the additional loss of heat to the sky, and partly because the temperature of the environment will be lower out of doors than indoors, since walls heated during a hot day do not cool at night as rapidly as objects outside.

C = conduction and convection of heat from the body by air movement. The air will warm or cool the body according as its temperature is higher or lower than that of the skin The rate of transfer is proportional to the square root of the wind velocity. If v is the speed of the air movement in metres per second, and temperatures are in ° C., then for the nude body

$$C = 15\sqrt{v}\,(T_s - T_a).$$

T_s, T_{cl} and T_a are the temperatures of the skin, clothing and the air respectively. For the clothed body

$$C = 10{\cdot}4\sqrt{v}\,(T_{cl} - T_a).$$

If the radiating parts of the environment are at the air temperature, then for the nude body

$$R + C = (3{\cdot}6 + 15\sqrt{v})\,(T_s - T_a)$$

and for the clothed body

$$R + C = (3{\cdot}6 + 10{\cdot}4\sqrt{v})\,(T_{cl} - T_a).$$

For so-called still air we may assume air motion of 4 cm./sec.

E = *loss of heat by evaporation from skin*

This rate will depend on the rate of secretion of perspiration, on skin temperature and on temperature humidity and rate of movement of the air. At low temperatures the secretion of insensible perspiration amounts to 20–30 grammes per hour, and its evaporation yields a loss of heat of 7–10 units increasing from the lower limit at low temperature to the upper limit as temperature rises to 30° C. At temperatures above this limit the active secretion of sweat through the sweat glands begins extending over a greater area of the body as the temperature rises until at an air temperature of about 37° C. the sweat begins to pour off the body and fall to the ground. The heat loss at this stage is discussed later.

B = *rate of loss of heat by breathing*

The air inhaled is raised to body temperature and raised to saturation at that temperature, a small but undetermined part of the heat taken from the body during inhaling being returned to the body during exhaling. The heat lost in warming the air amounts to about 1 unit at air temperature of 20° C. (70° F.), and only amounts to about 2·5 units at air temperature of 0° C. It is thus a very small item in the heat balance of the body and need not be further considered. The loss of heat due to the saturation of the inhaled air is estimated from the loss of weight due to the removal of water from the body and is measured in practice along with the loss from the skin. It is therefore included in item *E* discussed above.

Some rates of sweating

In the following table the first five items are frequently quoted as rates of sweating for an average adult.

At rest (insensible perspiration)	1/30–1/18 pint per hour
During moderate effort	1/7–2·7 pint per hour
Running	2½ pints per hour
Footballer	9 pints per hour
Oarsman	10–12 pints per hour
Miner (1)	2 pints per hour
Miner (2)	1·1 pint per hour
Cricketer (all-day match, Cairo)	17 pints

The figure given for miner (1) is the average for 13 miners at Pendleton Colliery whose individual rates varied from 1·4 pints to 2·54 pints per hour when working at the coal face in a temperature of 98 100 F, with wet bulb temperature 85° F (relative humidity 53 %) The figure for miner (2) is the average for 7 miners whose individual rates varied from 0·64 to 1·48 pints per hour, when working at the coal face in Hamstead Colliery, in a temperature of 82 F with wet bulb temperature 77 F (relative humidity 79 %) Both sets of data for miners are taken from Moss *Gases, Dust and Heat in Mines*

Sweat contains in solution small quantities of common salt, potassium chloride and other inorganic salts as well as organic compounds The amount of common salt in solution is very variable, the amount present depending on diet, amount of fluid drunk during the period under investigation duration of the period of sweating, and the degree of acclimatisation, but an average concentration of 0 3 % of common salt is probably a reasonable estimate The amount of common salt in insensible perspiration is negligible The lowering of the rate of evaporation of sweat from the skin below that of pure water, by the salts in solution, is too small to be significant But any garment worn all day during heavy sweating will take up a strong concentration of salt, and in consequence will not dry readily The amount of salt removed from the body during very heavy sweating can be sufficiently great to have serious consequences to health, if the loss is not replaced Miner's cramp is a consequence of loss of salt from the body, and can be cured by the addition of small quantities of salt to the water drunk during the period of work

The effects of humidity and air movement on evaporation of sweat

On the basis of analogy with the evaporation from a free surface of water we should anticipate that the rate of evaporation from the skin should be proportional to the square root of the wind velocity, and to the difference in vapour pressure at the skin and in the surrounding air We shall first consider the evaporative loss at different temperatures, when the air movement is kept constant, as in the experiments summarised in

fig 2 above If then the evaporative loss is divided by the difference in vapour pressure in air saturated at the skin temperature and in the ambient air the quotient should be constant if the area from which evaporation occurs is constant or alternatively should give a measure of the area from which evaporation takes place at different temperatures The quotient is shown in fig 2 as W It is seen that it increases rapidly as the air temperature rises above 31 C as secretion of sweat becomes more active with rising temperature reaching a maximum of 30 units at about 36 C At lower temperatures say below 31° C, the quotient W is nearly constant The maximum heat loss by evaporation is 30 units per cm of Hg difference of vapour pressure at the skin and in the ambient air

It might be expected that in air of high relative humidity the evaporation should be less than in air of low relative humidity, at the same temperature Experiments have shown that the evaporative loss is very slightly greater in relative humidities below 40 %, than in air of humidity up to over 80 % and the evaluation of the quotient W shows that in humid air the wetted area is increased so as to compensate for the lowered evaporative power of the air and maintain approximately the same evaporative loss of heat from the body The skin temperature is slightly higher in damp than in relatively dry air but a rise of relative humidity from 29-35 % up to 75 79 % only raises the skin temperature by 0 5 °C

Gagge (1941) has given diagrams showing the way in which the evaporative loss from the body varies with wind velocity, and has shown that an increase in air movement produces a decrease of the evaporative loss and a decrease of the wetted area This is the reverse of what occurs in the case of evaporation from a free surface of water An increase of air movement yields an increase in the convective loss from the body so that the maintenance of the heat balance of the body requires a lower evaporative loss with higher air movement The body reacts to the changed conditions by decreasing the wetted area of the body Thus it has to be recognised that the body exercises a delicate control which decreases the area of active sweating when the evaporative power of the air is increased, either by diminished humidity or by increased air movement, and increases the area

of active sweating when the evaporative power of the air is decreased, either by increased humidity or by decreased air movement.

In a warm environment, the effect of high relative humidity is to yield the rapid rise in the wetted area of skin shown by *W* in fig. 2 at lower temperatures than it occurs with low relative humidities, with a corresponding increase in the feeling of discomfort which is associated with the rapid secretion of sweat.

The reactions of the human body to changing relative humidity, as described above, cannot be reproduced in any instrument; and for this reason it is impossible to devise any instrument capable of producing a response strictly parallel to that of the human body. The kata-thermometer, devised by Sir Leonard Hill, has been widely used to estimate the cooling power of the air, the effect of evaporation being taken into account by covering the kata with a wetted fabric, from which water will evaporate. This instrument can be regarded as approximating to the human body when the body is completely wetted by sweat, a condition only attained in conditions of high temperature or during strenuous exertion. The cooling effect of the air on any wetted surface produced artificially will increase with increase of air movement, and with decrease of relative humidity of the air.

The effect on the evaporative heat loss of variation of relative humidity at low temperatures, say below 25° C. (77° F.), can have no marked influence on the heat balance of the human body, since the total heat loss by evaporation from the skin and in the respiratory tract is a small fraction of the total heat involved in the bodily exchange with the environment. Any pronounced effects of extremes of humidity at low temperatures must be due therefore to some other aspect of the heat balance, or to neurological causes. In air of high humidity and low temperature, conditions are usually described as *raw*. In such conditions, there is condensation of water in the clothing, leading to a marked increase in the heat conductivity of the clothing, and a consequent increase in the convective loss of heat from the body. Condensation of water in the clothing from air of high humidity is explained by the fact that most types of clothing have an affinity for water, and act in the same way as the condensation nuclei in the atmosphere. The discomfort

of extreme dryness at low temperatures cannot be so readily explained It cannot be due to increased evaporation, since at low temperatures we may probably assume that the insensible perspiration is evaporated as rapidly as it is exuded through the skin no matter what may be the relative humidity of the air It has been stated (Buttner, 1937) that the relative humidity of the skin, measured by means of a small hygrometer placed close to the skin is always less than that of the air Buttner suggests that the tissues of the skin contract in dry air, in the same way as the hair of a hygrometer, and that the discomfort of very dry air is due to nervous irritation produced by the contraction

It is sometimes stated that the discomfort of cold damp air is due to damp air having higher heat conductivity than dry air On theoretical grounds there is no reason to accept such a view, and experimental measurements of the conductivity of dry and damp air fail to reveal any difference

At high temperatures, the effects of variation of relative humidity on the evaporative loss of heat from the skin become very great It will be seen later that at air temperatures which approach the internal body temperature high relative humidity may so check the evaporative loss that heat balance cannot be maintained, and the body temperature rises in consequence of this When the air temperature is above body temperature, the body gains heat from the air by radiation and convection and the only source of loss of heat from the body is evaporation If the air movement is brisk the convective gain of heat from the air is great The body reacts to this by increased sweating, and the evaporation of sweat can maintain the equilibrium of the body temperature within certain limits of atmospheric conditions But if the body is exposed to these conditions for a long period, there is a risk of exhaustion of the sweat glands, after which the body has no mechanism capable of ridding it of the heat produced by metabolic processes or gained from the air by radiation and convection

The effects of clothing

The wearing of clothes protects the body from extremes of temperature, at both ends of the temperature scale Air is a

very poor conductor of heat, and the more air is trapped in the material of the clothing the greater will be the resistance to the conduction of heat from the body to the air The resistance can be increased by increasing the number of garments

The clothed body offers to the atmosphere a surface consisting in part of the outer surface of the clothing and in part of the surface of the skin on those parts of the body which are normally uncovered This surface has a temperature which is nearer to that of the air than has the skin of the unclothed body in similar environmental conditions Thus the clothed body must lose less heat to a cold environment than does the unclothed body One result of this is that the unclothed body begins to cool as soon as the temperature falls below 29° C while the lightly clothed body does not begin to cool until the air temperature falls below about 25° C At the other end of the scale, active sweat secretion begins at about 29° C for the lightly clothed and about 31° C for the unclothed body in still air

The experimental investigations made at the John B Pierce Laboratory and elsewhere cover a considerable range of temperature, but do not extend to temperatures near freezing point They do not therefore give a direct answer to the question of how far it is possible to maintain the body temperature at high level when exposed to a cold environment by wearing sufficient clothing Various observations by different physiologists have shown that when the clothed body is exposed to low temperatures, the temperature of the skin on the trunk is relatively little reduced, while the extremities cool considerably K Mellanby (1932) has described measurements in still air, made on his own clothed body, in a wide range of temperatures The skin temperature on the chest for given air temperatures, had the value shown in the table below

Air Temp ° C	41	30	28·4	18	0	3·8
Skin Temp (chest) ° C	36·9	36·7	37·3	33·5	32·5–33	31

The reading in the last column was made on the roof of the building, in light snow The table shows that the trunk temperature falls relatively slowly with fall in air temperature, and it may be inferred that, if sufficient clothing be worn, the temperature of the trunk can be maintained at a high level even

in low air temperatures, at least in still conditions. The temperature of the limbs will fall in cold air, though far less than for the nude body, the maintenance of high trunk temperatures favouring the flow of blood to the extremities, which in turn helps to maintain higher temperatures over the extremities.

The effect of wind in increasing the loss of heat from the clothed body has not been investigated quantitatively. It is clear that wind must produce such an increase, since it causes a greater penetration of the clothing by cold air, and there is an added effect due to wind penetrating through the openings in the clothing, so bringing cold air into immediate contact with the body, particularly at the neck, sleeves and legs of the clothing.

The data quoted above appear to show that the important factor in comfort in cold weather, when one is warmly clad, is the maintenance of the extremities at a comfortable temperature. It is possible to be comfortable indoors in cold weather, without artificial heating of rooms, by wearing sufficiently warm clothing, provided special care is taken to keep the extremities warm, the legs being covered by a warm rug.

The limit of evaporative regulation.

At high temperatures the body adjusts its heat balance by adjusting its evaporative loss, increasing the wetted area as the temperature rises. The limit beyond which evaporative loss cannot increase, in nearly still air, is about 30 units per centimetre of mercury difference of vapour pressure at the skin and in the environment. At high temperatures, this loss has to balance the gain from metabolism, radiation and convection, and if it is not possible for the balance to be maintained when the evaporative loss is at its maximum, the body temperature will rise, and will go on rising so long as the body remains subjected to the same conditions. Following Winslow, Herrington and Gagge (1937), we can write down an equation which will determine the highest relative humidity at any assumed temperature, in which heat balance can be maintained. The authors mentioned have given a set of curves showing these limiting conditions with a variety of intensities of air movement. These

curves are shown in fig 3 It is seen that an increase of air movement from 17 ft /min up to 100 ft /min reduces the limits of toleration in low humidities, and it is only when the air movement is increased up to about 500 ft /min , say to 6

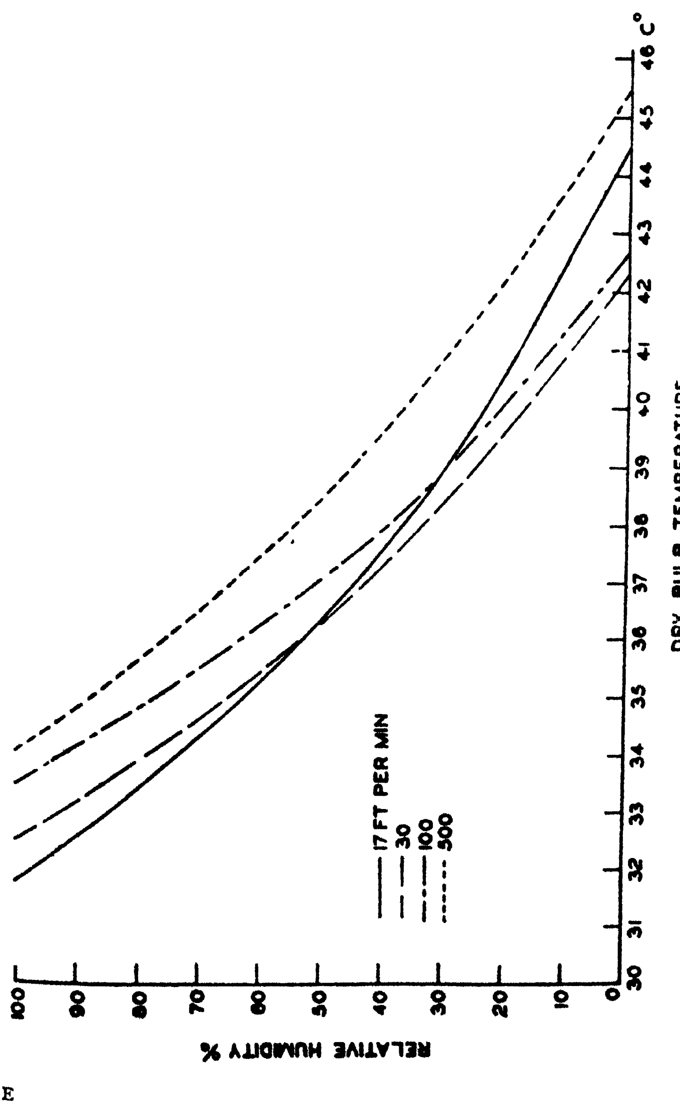

Fig 3

Contour chart indicating upper limits (wetted area = 100 %) of the zone of evaporative regulation for various air velocities Nude subjects (Gagge Herrington and Winslow, 1937)

m.p.h., that there is a net gain of comfort. Thus air with a temperature of 40° C. and relative humidity 20 % is tolerable with a wind of 17 ft./min., but intolerable with a wind of 30 ft./min., and in such conditions one would be more comfortable when sheltered from a light breeze, and indoors less comfortable with an electric fan working. This may explain why passengers on ships passing through the Red Sea seek shelter from the breeze. Still higher temperatures can be tolerated when the ventilation is increased, but it must be emphasised that these deductions from the curves of fig. 3 only hold so long as the sweat glands remain in operation.

In very dry air at high temperatures the sweat glands may become exhausted, so that evaporative cooling ceases to be effective, and the body temperature rises rapidly. Moreover there is a limiting wind which will evaporate the sweat, when it is being secreted at the maximum rate, as rapidly as it is secreted. An increase of wind speed beyond this limit will yield no increase of evaporation, but will increase the convection of heat from the air to the body, and the body temperature will then rise, and will go on rising, so long as the higher wind speed is maintained. The many deaths attributed to the simoon, the "Poison Wind" of South-west Asia, are probably to be explained by such failure of evaporative regulation of the body temperature, leading to death by heat stroke.

The limiting conditions prescribed by the curves of fig. 3 cannot be passed without loss of equilibrium of body temperature. This does not mean that it is not possible to live for a short time, without danger of permanent injury, in conditions which surpass the limiting conditions. Blagden (1775) has described how he stayed for eight minutes in a room in which the temperature was maintained at 250° F., sufficiently high to cook a beef steak placed in the room within 13 minutes. Blagden was quite unharmed by his brief stay in these conditions.

In fig. 4 are reproduced, as *AA* and *CC*, the curves for air movement of 17 ft./min. and 500 ft./min., from fig. 3, and a curve *BB* which gives the limiting conditions for a person clothed as described earlier, for air movement of 17 ft./min. It

is seen, from a comparison of *AA* and *BB* that clothes afford a definite protection in temperatures above a certain limit 96° F Two additional curves have been drawn, marked *DD* and *EE*, to indicate the limiting conditions for men doing sufficient work (nude) to raise their metabolic rate to 100 and to 150 units, respectively In the diagram are shown points indicating measurements of temperature and humidity in mines made by Sir John Cadman (1913) summarised by Moss (1919) The limiting conditions shown by curve *LL* should correspond to men doing light work underground and it is seen that the limit set by *LL* fixes reasonably well the conditions in which it is possible to work with any degree of comfort The limiting temperature for men resting with saturated air is seen to be 88° F in agreement with the usually accepted limit of temperature tolerable in saturated air in mines

In out of-door conditions the heat absorbed by the body from sun and sky radiation must be counted as an addition to the metabolic heat and must be dissipated along with the latter Thus the curve for *M* 150 in fig 4 might be taken as representing the limiting conditions for a man lightly clothed while doing very light work standing in bright sunshine, or walking at about 2 m p h on an average summer day in England For a lightly clothed man sawing wood we should have to take the value of *M* as 250 in fig 4 The limiting conditions would then be prescribed by a line running from 62° F for saturated air to 70 5° F for completely dry air

The climate of comfort health and efficiency.

No definition of comfort which will be acceptable universally can be given since bodily reactions to the environmental conditions vary within wide limits for different individuals The variations may be due to clothing acclimatisation and mode of life In such experimental investigations as those summarised in figs 1 and 2 above, the subjects of the experiments found maximum comfort when the skin temperature was near 33° C This means that maximum comfort is to be found in what was described as the zone of vaso-motor control which for the lightly-clothed subject when resting required air temperature

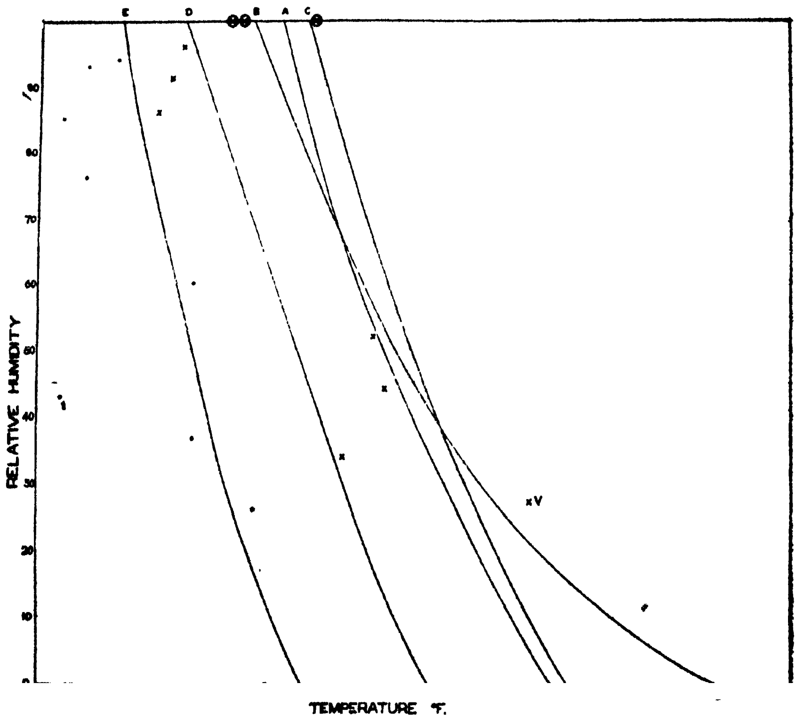

FIG. 4.

Upper limits of zone of evaporative regulation for nude and clothed subjects. *AA* and *BB* represent for nude and clothed subjects respectively the limiting conditions with air movement 17 ft. per min., and *CC* the limiting conditions for nude subjects with air movement 500 ft. per min. *DD* and *EE* represent limiting conditions for nude subjects with metabolism 100 and 150 units respectively. The points marked in the diagram show conditions in mines, as observed by Cadman. The dots indicate conditions in which some clothing was worn (point marked 1 men fully clothed). The crosses show conditions in which men worked naked, and the encircled crosses conditions in which men naked could do no effective work. The cross marked *V* indicates conditions with high degree of ventilation.

between 25° and 29° C., or 77°—84° F. These limits cannot be applied to persons living an active life, and we are forced to consider comfort on a purely empirical basis. In the control of indoor conditions, a range of temperature variation from 64° to 75° F., with relative humidity from 60 to 70 or 75 %, is frequently accepted as most comfortable in still air or in air with only slight movement. Such specifications differ in the

British Isles from those used in America, or from those normally used in Germany.

Both efficiency and health demand that, for a man living an active life, it should be possible to exert moderate physical effort without the risk of rise of body temperature, even in bright sunshine. It is suggested that, in fig. 4 above, the line of $M - 250$, which would extend from 62° F. for saturated air to 70·5° F. for completely dry air, would represent optimum conditions for an active life. The limiting line in fig. 4 would pass through the point representing 65° F. and relative humidity about 60 %. This specification agrees well with that given by Ellsworth Huntingdon (1919), according to which the optimum conditions for health are represented by a mean daily temperature near 64° F., with relative humidity of 75–80 %. Huntington substantiates his contention by a mass of statistical data which refer to the frequency of deaths in different countries with a wide range of temperatures and relative humidities.

For optimum mental work, Huntington specifies a mean daily temperature of about 40° F., again with moderate to high relative humidities. He gives, in *Civilisation and Climate*, fig 8, a curve of activity of students of mathematics in different weather conditions, a curve whose maximum is at about 38° F., with a steady falling off to very low values at 25° F., and a slower but steady fall with higher temperatures.

It must be stressed that the conditions which Huntington specifies for health and for mental efficiency are far removed from what would be prescribed for comfort. And it must be borne in mind that both health and efficiency definitely require a variation of conditions from day to day, without reaching extreme conditions suddenly, since sudden large variations afford no opportunity for acclimatisation. An occasional very hot day in England is not conducive to comfort, physical efficiency or mental activity.

When allowance is made for the variation of temperature in the course of the day, it is clear that a climate which produces a mean temperature of the day of 80° F. or higher, with the maximum temperature reaching 95–100° F., sometimes even 110° F. or higher, will not be suitable for the white man. Huntington, after a general survey of the climates of the world, comes to

the conclusion that a climate which produces monthly mean temperatures varying from about 60° F in summer to about 40° F in winter, should be the optimum for health and efficiency The nearest approach to this is the climate of the British Isles !

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A Plan for Planning.

By A. P. Simon

Unless we can plan widely, we shall not plan at all. If we look round we can see in Manchester evidence of bits of planning, and we can see even more in Salford. At the present moment there is a live interest in the refashioning of our City, and it is being expressed in a variety of ways by a variety of organisations. It is because there is evidence that we are not planning widely, that sectionalised preferences and tastes are being over-emphasised, that the need of a *Plan* for *Planning* is a matter of urgency. In due course the cultural urges should and will be met. Planning will create a demand which will arise naturally. In any case, culture cannot be imposed from above.

I take it that the pre-requisites for civic planning are agreed upon. They are the presumption that air-pollution (the domestic firegrate as the chief offender) will be a statutory offence and will be energetically dealt with , that social security and unemployment will be regulated ; that we can improve our democratic pattern in an atmosphere of peace. If we shape our plans with an eye on the Beveridge Report, I suggest that we shall not go far wrong.

My approach is based upon the conviction that *spatial planning is a social and economic* (or perhaps *domestic*) *problem*. It will need all the help that technology and architecture can give, but neither the creation of a new, nor the refashioning of an old or elderly, town like Manchester can be effectively carried out if we omit to keep the sociological aspect in the forefront of our minds. Technocrats and architects are our leaders, not because of their professional qualifications, but because they, more than others, have to supply the individual and collective wants of our citizens.

May I try as briefly as possible to explain what I mean by sociological problems : they are obvious but they need consideration :--

1. Planning springs from the needs of the citizens.

2. Citizens fulfil two functions. They are both consumers and producers: they have therefore two main needs :—
   (*a*) They need homes from which they do the spending.
   (*b*) They need workshops (factories, warehouses, offices, etc.) from which they draw their earnings.

Planning can therefore be summarised as the consideration of *where you live and spend your money and where you work and earn your money.* In the flow of goods and persons between the two lies perhaps the main problem of the public authority. The place of work is under normal conditions the centre of the town, just as the place of residence is on the outer rings. This is emphasised in what is an essentially British pattern of suburban life.

From the home the shuttlecock moves towards the centre and then back to the home as in the end the most important consideration. The week is made up of seven times twenty-four hours. Of these say forty-eight hours are spent at work. This leaves 120 hours to be spent in the home or with the home as a background. Do I need to add further that :-

1. It is in the home that the citizen experiences family life.
2. It is the possession of lodgement that gives the franchise and the right to vote.
3. The home is itself the workshop of a very important, a very hard-worked and a very much underpaid section of the public—the mother, the wife, and the housekeeper.
4. It is the home and its upkeep that absorbs our earnings.

Our daily wants, our clothes (those that we are not wearing), our furniture and household utensils, the little luxuries, and coal (as long as we still demand it) are all used and stored in our homes. They come in various ways, either through the local shops or from the big stores in town. They may be delivered to us, or we may fetch them, as we are doing under war conditions. With few exceptions they come either directly or indirectly from the centre. This then is the case for starting from the home.

We have therefore a daily pattern with a morning movement of persons townwards— so that for the vital hours of the day the centre carries the main inrush of civic life It is therefore permissible to discuss the centre before we come to the important considerations of the home

The Town Centre

The central core holds the workshops or places of business in which the citizens draw their earnings These are important from a planning point of view, not so much because they contribute so substantially to the municipal budget but because so many hundreds of citizens earn the money which enables them and their wives to meet the daily needs of the home

Important as is the function of export and wide distribution it still comes second to the task of supplying the needs of the citizen We can cease for quite a long time to export our products but if we cease to supply the daily recurring needs of our fellow citizens and ourselves we die of privation

This sociological approach produces an entirely new set of values What in the past we rated as most important was the export trade and we gave it pride of place The firms which were housed singly in the warehouses of Portland Street, or in groups under the roofs of Lloyds' or Booth & Others' packing warehouses, came first A great gulf separated them from the retailer, no matter how big was his concern Now the position is reversed the big retail store may employ the same number of citizens as the congeries of shipping firms in one of our big packing houses, but in addition the former serves the citizen with the things he needs We must shift our eyes to the Lewis's and the Kendal's, even to Woolworth's, possibly to Ryland's and to Watts's, certainly to the Co-operative Wholesale Society The last-named is particularly interesting, for it alone has its own organisations at both ends, and it is of course the home end, i e, the local branch, that is the senior partner

If proof be needed of the importance of the impact which the big retail store has upon civic life, we have the examples of the arrangements which Kendal's have made for garaging their customers' cars behind Deansgate, and the easier problem that they have in being on the outer periphery of Deansgate.

Lewis's, whose similar effort has been stopped by the war, will be less well placed because they are on the inner side of Market Street and Mosley Street

It is these crowds of customers who either with cars or on foot flock to the retail shops that contribute to the civic problem The exhortation to shop early implies a restriction which a "plan for planning" may remove

But we have still one more organisation located in the centre core to consider one that is under municipal control and is therefore the property of these same citizens whose needs it serves This is the Markets Organisation from which flow outwards the most perishable and the most necessary of our commodities Morning after morning vehicles of every sort move outwards from the markets to shops near to the homes of our citizens Our main market is Shudehill, but we have a fruit market adjacent to the Ship Canal in Hulme and our meat comes from the abattoirs with which we have saddled the threshold of Salford There is a practical reason for the location of each, but there is no reason why one of our first efforts in re-planning should not be directed towards uniting these utilities Two of them are dependent on the railroads with which they are actually linked up the third is in connection with the Ship Canal, and again we find that this enterprise, which was first conceived as an adjunct to our export trade, finally achieved its measure of success by the facilities it created in the importation of commodities for Manchester and other places [1]

The Railways

We shall not want to re-plan the Ship Canal, we shall work round it as though it were something of nature's own handiwork, but the railways should be amenable to communal re-planning New legislation or voluntary collaboration will be needed, for, as matters stand at present, local authorities have no powers to include railway property in their plans Stations, goods yards, warehouses, permanent ways are the rocks on which the waves of planning may be shattered There is the further tie-up with

[1] It is a matter of wonder that neither Manchester's port nor the ships that come to it bring us the one obvious commodity—fish—which comes by train from Fleetwood and other places and is said to go back to Blackpool!

the markets, and quite apart from these considerations there is the urgent need of release from the iron band that encircles the centre core. There is also the unravelling of the tangle which, dating back to the independent existence of the L. & Y., the G.C., the L.N.W.R., the Midland, is still extant, although the unification has for many years been under the L.M. & S.

The services that the railways render fall into three groups :- the handling of goods and freight, the conveyance of long-distance passengers, and the suburban daily in-and-out movement. Each required differing considerations and each links up with corresponding services on the roads and in the case of freight—with water-borne service. The handling of freight has already been considered in relation to our wholesale markets. The reorientation of goods traffic further from the civic centre seems to the non-expert to depend on the easier handling of goods conveyed from outside by rail and then sent outwards by road. The release from freight will allow for freer use of passenger trains, which as they enter the city should be transferred to electric traction and contribute to the relief of air-pollution. The long-distance passenger traffic should if possible be centred in one modern station worthy of being considered the ceremonial gateway to Manchester. It should be sited on some important open space so that on entering the city a pleasant vista would greet the new arrival and the station itself would be a pleasant point of departure. It should be possible for those laden with hand luggage and encumbered with small children to join a bus without having to negotiate a long station approach. Bus stations should be attached to railway stations in all cases. The local traffic should lead into an inner circle so that the furthest parts of the city could be reached without change.

General Arrangement. In the Centre Core.

Once we are rid of the above difficulties and have cleared away old buildings that are no longer profitable or attractive—the kind of buildings that emit black smoke from open fire-grates—we may hope to find spaces ample enough to develop cultural centres sited on green swards with bright flower-beds. One very necessary thing must, however, precede this consideration : we can no longer tolerate the open sewers which masquerade

as our rivers. The Irwell, the Irk, and the Medlock must be culverted (like the London Fleet or Westbourne streams) or they must be purified. In the latter case they will offer amenities that are desirable. Manchester once had its ponds and fountains in front of the Old Infirmary: I remember one solitary fountain in Albert Square. To-day Manchester has no lake or pond or fountain to be seen by the casual passer-by. And as the blitz has given us some justification for immediate action in the central area, I hope to secure ample setting for the replacements and even for existing buildings of character. Among these I would include not only public and semi-public buildings, but also privately owned blocks that had monumental characteristics. I would perpetuate some of the vistas that have so dramatically been opened up, particularly those that give such scale to the tower of our cathedral (e.g., the long approach from Deansgate).

It is, however, no good making our centre attractive for the stranger if our own citizen spends most of his time and all his leisure in the outskirts. We must first see what we can do there. First things must come first.

Where We Live.

The exercise of citizenship, such as it is, is practised from the home. The home is away from the city and it is one of our major problems that there is an ever-growing tendency to go further and further afield. Manchester's spread has already caused alarm. We have for generations encouraged people to become more and more suburban-minded; always to move further and further out, carrying with them our urban habits and our urban mentality and leaving a corresponding void in our city's make-up. The process has cost us the urbanity of the town. We have lost the meaning of the word "urban" as we have lost the meaning of the word "suburban." To be suburban is in reality to be "Mock-rural." We have deliberately spread spoliation in our countryside by treating it as the scenic background of our still urban mode of life. Keeping-up-with-the-Jones's has impregnated our whole design for living. As soon as we catch up with the Jones's in Fallowfield or Chorlton they move out to Wilmslow and Bowdon; when

we get to Wilmslow and Bowdon they move to Chelford and Knutsford. Up to quite lately this only affected the well-to-do and the rich. The latter, always a tiny minority in terms of population, set the pace and their influence was widespread. It was what *they* did and what *they* left undone, not as leaders of industry but as indifferent citizens, that has given us the untidy spread that is called Greater Manchester.

Until recently there was still a majority of citizens living an urban life housed in terraces and rows in tightly-packed streets; theirs was an urban, if not an urbane, life, for residence in such areas was a token of poor circumstances. Since housing became a national responsibility and subsidies were available for better dwellings, the suburban outlook was introduced into these sections of society. We have still far too many rows of tightly-packed homes in long drab streets, but many who have lived in such surroundings have been transferred to municipal or privately-owned estates either as municipal tenants or owner-occupiers. They have become also suburban-minded, while those who have been left behind, but who are in expectation of transference, share the same outlook though not yet sharing their experiences.

The housing concept of twelve-to-the-acre intensifies the problem of planning. It substitutes one kind of suburban life for another that has given a new set of difficulties in exchange for the old ones. A map prepared by the City Surveyor shows the relative acreage covered by the cottage type of house (rateable value under £25) coloured orange, and the larger type coloured red. The result is orange in every direction with streaks of red bulging here and there. Only a few years ago the map would have looked quite different, having white hinterland where we now have corporation estates.

We must think in terms of these new estates which now cover so much of the face of our city; the best examples are those owned by the city. Socially they count for less as they imply a lower range of income than that enjoyed by the owner-occupier, whose home is no bigger and infinitely less seemly. To think in other terms than the orange colour of the map would be sheer folly. The fate of the red part is too ominous, for this type of dwelling is tied up with the economic reshuffle which war conditions have accelerated. Quite apart from reduced

incomes which have made the upkeep of big houses prohibitive, the entire liquidation of domestic service has altered the social structure and has considerably ironed out the class differences between the "red" house and the "orange" cottage. Such houses are either empty or are converted into tenements and flats. Some have been turned into institutions, while in the remaining ones the owners tuck themselves away in one or two of the smaller rooooms. The disappearance of this class of property is only a question of time: with them will go some of the few remaining amenities that Manchester possesses. Plymouth Grove has gone; so too has Woodlands Road in Crumpsall and the stretch of Wilmslow Road between Withington and Didsbury villages. Whalley Range has been invaded, while it is a matter of surprise that Victoria Park has conserved its sylvan character though its mansions are converted to various uses.

The substantial mansion has little to offer architecturally, but its contribution of tree-lined roadways will be missed more than the actual building. Much has been sacrificed needlessly: we have legislative powers to conserve amenities and if the smaller houses which have replaced the mansion had only conserved the same building line and setback, if trees could have been preserved by leaving the footpaths at a higher (and probably safer) level than the carriage-way, much that was pleasant could have been saved. These departed glories loom deceptively large, for they lined continuously two or three of the more favoured highways—Wilmslow Road, Bury Old Road and Bury New Road, Eccles Old Road, etc. These have numerous bulges, which were however less in the public eye, though there was an intangible comfort in knowing they were there. Behind these was open country, on the south side of which were grazing grounds for cattle and fertile acres for crops.

Now these triangles, having their base on the outer periphery and their apex towards the centre, are covered with a network of small property: nearer to the town centre it is of the grid-iron lay-out, further out it is of the twelve-to-the-acre type. These hinterlands which now house the average citizen lack any semblance of coherence. Even the new housing estates designed as complete units have lost their individuality and spread monotony through not being suitably separated from one

another. The tendency on these triangles has been for lateral development, rather as the branches of an espalier fruit-tree are set out. Parkways for through traffic, green belts as an alternative to recreation grounds, and parks sufficiently wide to take a football ground and a cricket pitch, would divide one estate from another and link up the main arteries from the city. In addition to this lateral development these triangles should have their own main avenue stretching townwards and forming the stem of the espalier. I suggest that these would terminate within the periphery and would debouch not from the centre of the city but from the inner circular road marking the outer boundary of the inner core. The effect of planning in this chequer board fashion would be to cut up the triangles into the desired neighbourhood units on which community life could be properly developed. As a by-product, it would relieve the congestion on our arterial roads, leaving them freer for the traffic moving to beyond the city boundaries.

The outer rings, viz., the broader parts of the triangles where the new estates are situated, would perhaps only need some relatively slight adjustment—some emphasis on what has so recently been created. The inner part, towards the apex, where we find nothing but the out-moded and largely outworn form of housing, calls for something more compact than the twelve-to-the-acre concept. The British Medical Association has just given its blessing to flats. I suggest that in these near-by areas, if indeed not elsewhere, we must shed our prejudices if we are to have the necessary open setting. After all, flats are merely rows of houses placed end-up, and in this vertical position each home enjoys the requisite amount of sunshine and fresh air.* The idea that anything over sixteen houses to the acre produces overcrowding is of course fallacious in vertical development : it only applies to the horizontal.

Whether we plan vertically with flats or horizontally at twelve-to-the-acre, we must provide for amenities for a corporate life, such as Community and Health Centres, British Restaurants, Day Nurseries, Employment Bureaux, not to mention schools suitably sited so as to combine with the above services. A terminal bus station might be a practical and social feature of a neighbourhood unit. It could combine the features of an open

forum and an information bureau (Citizens' Advice Bureau). It would become the gateway to the community that it served and be provided with waiting and retiring rooms for public use.

I should like to see a plan made as an experiment on the two sections which abut upon Hyde Road, viz., the triangle between it and Stockport Road and (until the railway sidings are cleared) on the triangle between it and Ashton Old Road. The city end would start from Ardwick Green, which offers an opportunity for imaginative treatment. My chief reason for choosing this segment is because it contains Belle Vue.

Belle Vue.

The value of Belle Vue to the community is by no means properly assessed and its development, whether as a civic or as a privately owned enterprise, conjures up infinite possibilities. It is, *par excellence*, the place where our cultural intelligentsia can most usefully make contacts with the ordinary citizen. Its fame is a household word far beyond the confines of the city and has been so for the best part of a century.

I would have Belle Vue a focal point. I would have it approached ceremoniously from all points of the compass and I would rehabilitate Plymouth Grove, which still has vestiges of past dignity, restored from its faded glory. There is nothing locally to compare with Belle Vue, though some of us can remember Pomona Gardens and Knott Mill Fair. Civic planning should not be oblivious to the Football Grounds, the County Cricket Ground, and the Racecourse.

All these are regional character, and the more clearly the "plan for planning" develops the more clearly does it become apparent how much regionalisation affects Manchester and how far Manchester affects the surrounding regions.

Regionalisation : Salford, Stretford and Ourselves.

The civic centre, so void of citizens, is "Manchester" not only to those who live within the city's border but to millions more who live beyond. The difference between those who live in the outlying dormitories and those who live in the suburbs is merely that the former travel in and out by train and the latter by bus. Those who live in the south-east Lancashire

conurbation may have their own civic life, but they too look on Manchester as their provincial capital. The institution of the Regional Commissioner for No. 10 Civil Defence Region has set the official seal on what was in being for a long time. It has brought the consideration a step beyond that of permanent utilities, such as electricity and waterworks. It is a big jump to regionalised police and fire services. The tie-up between regionalisation and Manchester's central core is crystallised and the only thing that need trouble us in the acceptance of regionalisation is its method of administration. *There can be no valid objection to regionalisation provided that a democratic formula can be found.* The problem is how to fit in a new authority between the local statutory bodies, with their control on the areas that they govern, and Whitehall. It sounds difficult, but something of the sort has been done in the case of the London County Council that may help us to safeguard the democratic control at present lacking.

Willingness to co-operate and goodwill are also factors to be considered, and these too are of outstanding importance in considering the regionalisation of Greater Manchester, that is, of uniting Salford, Stretford, and ourselves. We in Manchester can view a fusion with equanimity : we have a place in the sun (air-pollution permitting) : we cast the shadow of our greatness upon the other two. What can be done to help Salford? What has she to offer to the general pool? She has a very fine artery in the shape of Chapel Street. Chapel Street has width and has, besides the Crescent, several interesting set-backs—the Town Hall, St. Phillip's Church, the triangle at Cross Lane, and the vestiges of Leaf Square. She has the magnificent possibilities of Peel Park and the Crescent, which flank what is certainly our best example of undeveloped area, viz., the open space contained within the big loop of the Irwell. She has also the wooded slopes of Higher Broughton and Kersal. We can help by planning for a better link-up where Chapel Street ends miserably in the labyrinth of Exchange Station arches, and so bring part of Salford into the Centre Core. There might be a connection of a boulevard character between Old Trafford (Throstles Nest) and the Crescent, and between Peel Park and Higher Broughton, which would fit into a circular or semi-circular roadway round

Greater Manchester. Salford could be made the administrative home for the many regional organisations and thus have the same sort of status that Westminster has to London. In doing this we should be giving back something that we have in the past unwittingly taken away. We could readjust the disparity which shows up so clearly on comparison of the proceeds of the penny rate, which in Manchester produces over £24,000 and in Salford only £4,000.

There is not much that we can plan for Stretford, for in her case we are not quite so much on top of one another. Only an outlying portion comes into the Manchester rings, and this could be neatly fitted into the general plan and would straighten out the congestion at Trafford Bar, where so many arteries and crossroads converge, calling for very drastic rearrangement.

Manchester must give careful attention to its neighbours and particularly those which are separated not by geographical boundaries but by administrative barriers. *Local pride is the main obstacle that will have to be overcome.* We may have cleared the first ditch by securing a joint effort from our permanent officials, but sooner or later an authoritative council will have to come into being to carry out the plans which they create. Until such a body exists each local authority will remain responsible and such methods as they use will colour all future development. It is therefore important to find out exactly how such bodies are functioning now.

Why is it that in Manchester the matter of spacial planning is taken up by two groups of its citizens, working on parallel lines and so to speak never meeting? The Voluntary Societies supply the one group, the City Council the other. We must remember that the latter body has its own committees for "Town-planning and Buildings," for "Housing," not to mention "Highways," "Transport," "Parks," "Traffic Congestion" and others. Why is it that there are so few people who are members of such voluntary committees and at the same time members of the City Council? Why is it that the leaders of industry have so little contact with the inner workings of the City Council, when as a matter of fact the inner core from where these leaders operate has a representation of twenty-one Councillors and seven Aldermen for the 23,759 voters in its seven

wards ? [a] (Compare this with the representation of the Withington Ward with its 25,008 and Chorlton cum-Hardy with its 21,684 voters, which have each to be content with three Councillors and one Alderman.)

The answer to these queries is to me at least quite clear. The system practised for the choice and return of our elected representatives is too rationalised and is far from democratic. The practice of delegation to municipal committees is too sectionalised and has set up barriers and created vested interests within the civic government. People are nominated as Councillors not for considerations of personal suitability or for their relationships with the neighbourhood but entirely to suit the ticket of the political parties. Once they become members of the Council more than half the time is spent on political strategy and in scoring off the opposing faction; routine business occupies what little time is left. Municipal elections are merely an annually recurring rehearsal for the less frequent parliamentary election. You can become a member of the City Council with no real desire for local government service but merely because you have been useful or because you may be useful to the particular political party to which you belong. Sometimes the City Council is a convenient step towards Parliament. Motivated in this way, it is not surprising that the civic authority is so little alive to the social pattern and that it is left to others to take up causes and to make plans.

[a] The inner core — the city proper — is made up of the seven oldest and the seven smallest wards of the Municipality. Their residential population is ever dwindling and the voters in many cases are those who have privately owned businesses which in these days of Limited Companies which have no personal votes are growing less and less.

The seven wards and their electorate are respectively:—

St John's	1,850
Oxford	1,694
St Clement's	1,090
St Ann's	1,870
New Cross .	8,643
St Michael's	6,176
Collegiate . .	4,436
	25,759

Just compare St Clement's 1,090 and Oxford's 1,694 with Withington's 23,759 and Chorlton's 21,684!

In making spacial plans we are providing the wherewithal for better conditions of living and to do this we must have the planners as well as the plans Quite apart from the shortcomings I have tabulated above there is a feeling that the individual citizen should be brought into closer touch with his municipal representative by the collective medium of smaller neighbourhood groups which would concentrate on special needs and foster the civic interest of those whose lives are spent in close proximity

G H D Cole in his recent book Great Britain in the Post War World says

> Democracy begins at home and home is not the world or an island inhabited by forty million people but the little space which each of us is able to reach by converse and contact in action with his friends his neighbours his partners in the working part of life

The neighbourhood unit bridging the gap between the individual and the City Council the regional body uniting the threads of the different local authorities and linking up with the national government gives a promising formula for fuller democratic practice and for increasing civic responsibility The special planning advocated in these pages goes as far as the regional requirements demand after which it passes along with others into a nation wide plan This nation wide plan rests upon the needs of its citizens and the circumstances governing each one s daily life

APPENDIX 1

Air Conditioning and Noise

The domestic fire is the most difficult factor in planning for a better city because it is the chief agent of air pollution However cheap coal may be we pay enormously in washing repainting, replacement of stone and metal eaten by acid smoke and most of all in ill-health through lack of sunshine and long journeys accompanied by long waits in queues on cold nights Peoples no less civilised than we thrive in hermetically sealed rooms with double windows warmed by a closed stove that gives no smoke The discomfort of draughts draws us to the fire as a winter focus but in summer we gather towards the window. Electricity gives us the chance of strip heating around the window and of arranging the light there too Were we less cumbered with smoke our gardens would be better and, with even warmth in our rooms the windows looking out into the sunshine would be at least as attractive as is now the fireplace which bakes one side of us and leaves the other cold In flats at least central heating and air conditioning such as is spreading in many warehouses would make the problem still easier and the open grate could be discarded In homes too the open wood or coal fire should be restricted as much as possible a tax on each open grate might be a practicable step if electricity were cheap

APPENDIX 2

Help for Planning might come from a serious study of hours of work and work-shifts With a replanned city few people should be condemned to leaving home before 8 in order to reach their place of work at 9-30 and should have to face an hour and a half on the journey back in the evening Shift systems could help. Schools and Colleges might be arranged to begin and end at times when the rush is not at its height Even a six-day week system, such as is worked in Russia, is worth considering

The Human Senses, especially Sight and Colour Vision.

By J. H. Shaxby, D.Sc.

The hypothesis I wish to lay before you this evening, like the atomic theory of matter, is supported, not by direct evidence—no one has actually observed an atom—but on the agreement of the conclusions which follow from it with a considerable body of experimentally known facts.

It is a hypothesis of the mode of action within our various sense organs which results in the nerve discharges causing sensation. It is based on the striking similarities of those actions, so utterly different as at first sight the senses of vision, hearing and touch seem to be.

The stimuli which bring about sensation differ indeed profoundly among themselves; electromagnetic waves through space exciting vision, fluctuations of atmospheric pressure causing sounds, mechanical force on the skin giving the sensation of pressure, chemical substances evoking smell or taste, what could be more varied? Yet all alike give rise in their respective sense organs (a better name is receptors, and I shall usually employ that term) give rise then in their appropriate receptors to identical neuro-electric phenomena. Their energies, of such different kinds, are somehow converted within the receptor into electronic energy, which produces action currents in the nerve fibres associated with the units of the receptors, the rods and cones of the eye, the hair-cells of Corti's organ in the ear, the various touch or pressure, warmth or cold sensory corpuscles in the skin, and the rest.

These action currents are of the same nature for all, little bursts of negative potential which are propagated along the fibre with definite speed, each succeeded after an interval of quiescence by a second, this by a third, and so on; the whole series makes up a rhythmic discharge which is the stimulus to that part of the cerebral cortex which is their terminus, and so is the ultimate cause of sensation.

The currents thus resemble the handing on of buckets of water by a chain of men, rather than a continuous flow in a pipe, and they are like that chain also in that each burst or packet of action current can carry only so much energy, no

more and no less as a bucket can hold only a fixed quantity of water If the urgency to put out a fire increases the extra amount of water can be brought to the flames only by speeding up the passing of the buckets from hand to hand so here the increase of a stimulus which produces a heightened sensation results in a quickening of the rhythm but in no way increases the individual packets of energy What is termed the All-or-None Law applies the action current bursts only appear when the stimulus exceeds a certain threshold value but above that they are always of the same size

This mode of activity as I have said is common to all the senses the time interval between discharges and the rate of travel along the fibre vary from sense to sense and from one species of animal to another but it is of the same kind for all and for a given nerve fibre can only be affected broadly speaking by a change in the intensity of stimulation bringing about a change in the rhythm

Why exactly similar discharges should give rise one to hearing another to vision yet others to taste or smell or sensations of touch or warmth, is not a question which physiology can answer It is one aspect of the general mystery of the relation of matter to mind and as yet at any rate, lies outside the purview of experimental science

Another common feature involves sensation itself the so called Weber Fechner Law holds good for all senses, at any rate approximately and within strict limits The law affirms that the strength of a sensation is related logarithmically to the strength of the stimulus that causes it, or, as an equation $S = K \log I/I_0$ where S is the sensation I the stimulus, and K and I_0 are constants

The law has come in for a good deal of criticism one school of thought goes so far as to maintain that a true scale of sensation strength is impossible and that our estimates of warmth, for example, are really estimates of the stimulus The nurse testing bath water uses her elbow as a crude thermometer and so with the other senses Be this as it may, there is little doubt that our introspective judgments of the strength of sensations do run more or less parallel with a logarithmic function of the intensity

of the stimulus, within a range of intensities which is approximately that met with by the sense concerned in ordinary life.

To come to my hypothesis: I attribute these similarities to a specific mechanism, the same for all receptors. I postulate that a stimulus sets up disturbances within the molecules of receptor substance of the nature of vibrations, and that if these vibrations exceed a certain threshold strength an electron is jerked out of the molecule. This electron becomes a brick in building up the charge which ultimately discharges as a unit of action current, the packet of constant energy of which I have spoken. I term the energy thus set up the Receptor Energy.

For mathematical analysis I use the familiar equations of vibrations with dissipation of energy, in other words of vibrations which, if left to themselves, are damped and eventually die away. Our problem is the examination of the behaviour of a particle executing such vibrations under stimulating energies of various kinds. The full mathematical treatment will be published later and I need not weary you with it to-night; we can see the main conclusions for different cases with a minimum of formulæ.

If the stimulus is a steady one, such as that of constant pressure on the skin, the final result must be a definite displacement of the disturbed particle, just as a steady blast of air on the bob of a plumb-line finally brings the line to rest a little out of the vertical. But during the time taken to attain this final equilibrium the plumb-bob swings to and fro about the point at which it finally rests, and these vibrations gradually die away. Our supposition is that, so long as these vibrations exceed a critical magnitude, each results in the ejection of an electron, building up the receptor energy. The number of electrons is obviously equal to the number of swings which take place before they die away to the critical value, and it is easy to show that this number depends directly upon the logarithm of the energy of stimulation. Thus the receptor energy, proportional to the number of ejected electrons, is also thus related: in fact, if we call the receptor energy S we find that $S = K \log I/I_0$. In other words we arrive at the Weber-Fechner Law. S is now the receptor energy, the immediate stimulus of the action currents

and of sensation, not the introspective judgment of strength of sensation itself. The two are proportional, as so often happens with an effect and its immediate cause.

Now this energy is produced in a limited time and ceases when the damped vibrations fall to their threshold critical value. In other words, sensation ceases after a gradual decrease, although the stimulus has been kept constant. This precisely characterises senses which are commonly evoked by a constant stimulus. Thus the steady pressure of a pin upon a finger causes at first a pricking sensation which rapidly decreases until it dies away altogether. A more familiar instance is the fact that we are conscious that we are wearing a collar only for a short time after we put it on. The violet pickers of Cornwall, exposed to the steady stimulus of odorous vapour, soon become unaware of the scent, and those who roast coffee similarly perceive its fragrant aroma only for a quarter of an hour or so

The next case to be examined is that of periodic stimuli, those of hearing and sight. The stimulus, consisting of waves, is now itself rhythmic, and the equation of motion of the disturbed particle can be shown to contain two terms, one representing damped vibrations of the same nature as before, the other vibrations in unison with those of the disturbing sound or light waves. The amplitude of both these sets of vibrations depends not only on the strength of the stimulus but also, to a marked extent, on the frequency of the incident waves.

The cases of hearing and sight require separate examination. The frequency of sound waves is of the order of twenty to twenty thousand per second, while that of molecular vibrations is ordinarily of the order of a hundred billion per second or more. Hence the damped vibrations set up by the arrival of a given sound wave have time to die away in the relatively enormous period before the arrival of the next wave. This then acts as a new stimulus, and so receptor energy is generated as long as the sound waves fall upon the ear. Hence sensation also persists; there is none of the fading characteristic of a steady stimulus.

For light waves the case is different again, for now the frequency of the waves is comparable with that of the molecular vibrations: in fact we shall find reason to believe that the

natural frequency of the receptor particle is that of the greenish-yellow light to which the eye is most sensitive.

It can be shown that the effective stimulus I is given by the expression

$$\frac{n^2E}{(\omega^2-n^2)^2+4k^2n^2}$$

where E is the strength of the external stimulus, the light waves, n is a measure of their frequency, ω the measure of the frequency of the molecular vibrations, and k is their damping constant.

The expression shows that as n gets nearer and nearer to ω, the light energy E remaining fixed, the effective stimulus increases to a maximum when n is equal to ω. We have in fact a case of resonant vibration of the particle under the action of the light waves.

In the case of vision the receptor energy S must correspond to the brightness, and for this we have available data relating its changes with change of wavelength of light through the spectrum, for a fixed energy supply, the data of the so-called Visibility Curve. We can therefore test our hypothesis quantitatively, by determining the values it gives for this visibility throughout the spectrum. The theory leads to the equation

$$e^{1-S}=1+\frac{(\omega^2/n-n)^2}{4k^2}$$

S being expressed in suitable units to make its maximum value unity, as is conventionally done for the experimental data of the visibility curve. Hence the graph of e^{1-S} plotted against $(\omega^2/n-n^2)$ should be a straight line. This is found to be the case for wavelengths not too near the ends of the spectrum where the visibility is low. The expected relation holds for wavelengths between about $0{\cdot}5\mu$ and $0{\cdot}62\mu$. The slope of the line gives the value of the constant $4k^2$ as $0{\cdot}16$. Adopting this value we can calculate the visibility S for all wavelengths. In Table 1, the results of such calculations are shown. The successive lines are concerned with wavelengths which have various visibilities, the two wavelengths in any given line possessing the same visibility. In the first place it will be seen that the geometric mean between the wavelengths of such a pair has a constant value, for those wavelengths for which the straight-line relation

was valid, and this mean is that of the light for which the eye has maximum sensitiveness, i.e., when $n = \omega$. This is a familiar property of resonant relations, and is a partial verification of the correctness of our hypothesis. But further, the calculated values of the visibility, shown in the fifth column, agree closely with the experimentally known values tabulated in the first column, within the wavelength limits indicated. Outside these limits the agreement fails, and in fact near the ends of the spectrum, i.e., for low visibilities, the calculated values are negative, a meaningless result.

But such discrepancies are to be expected from the complete theory of receptor energy. It would take us too long to go into details this evening, but in brief the point is this. All the elements of receptor substance cannot be equally well placed to receive the energy of the stimulus, and those less favourably situated, getting less than their fair share, will reach their threshold as the supply of effective energy diminishes, before those more favourably situated, and will consequently go out of action. The remaining elements, on the other hand, getting more than an average share of the stimulus, will persist in producing receptor energy, and so have effectively a lower threshold. This means that the Weber-Fechner Law must break down when the stimulus is not far above threshold, as in the case of these lower visibilities. In fact we know from observations of all the senses that the law does fail, well before the threshold is reached. A plausible assumption as to the way in which the stimulus energy is shared among the receptor units indicates that the law for such small stimuli should be of the form $S = C(I - J)^2$, where C and J are constants. Thus $\sqrt{S}$ is proportional to $(I - J)$, and this proves to be the case for the relation between the experimental values of these low visibilities and the values of I calculated on our hypothesis. Applying the new equation to these cases, we obtain for the calculated values of the visibility the figures of the sixth column of Table 1. Agreement with the observed data is now complete throughout the spectrum.

One point remains: we have been considering the behaviour of the eye as a whole. If we consider individual elements of the retina, certain further conclusions can be drawn. It is well

known that the action of light upon the retinal elements is of a photochemical nature, a photo-sensitive substance is broken down by the light, and is reconstituted by the metabolic processes in the molecules of the receptor substance. These chemical changes are presumably related to the electronic ejections of our theory, and examination of individual retinal elements might be expected to show evidence of the phasic, i.e., temporary, activities under a steady stimulus, which we considered earlier in this paper. The onset of illumination will then cause transitory bursts of receptor energy, and therefore of action current, in some elements. In other cases the disturbed molecules, returning to their equilibrium positions on the cessation of stimulation, will show similar bursts of activity when light is shut off from the eye. Now Hartline has examined the action currents of individual retinal nerve elements and has found such phenomena to occur. Some continue to give action current throughout the period of illumination of the frog or turtle eyes upon which his observations were made, while others showed temporary bursts only at the onset of illumination, others again only at its cessation.

[A model, illustrating the phenomena described above, was now shown, consisting of an electric circuit containing an "Osglim" lamp, through which the discharge could be made either continuous or in flashes at longer or shorter intervals. This represents the stimuli, steady or periodic. The vibrations of a suspended magnet under the field of these stimuli represent the production of receptor energy. The model illustrated the production of temporary, phasic, activity under a steady stimulus, of maintained vibration under recurring stimuli with long pauses between successive stimuli, and of resonant effects when the frequency of the stimuli was of the same order as the frequency of vibration of the suspended magnet.]

I pass on to the subject of Colour Vision. The theory most generally accepted to-day is that associated with the names of Young and Helmholtz. It supposes that there are three structures or mechanisms concerned in the perception of colours, one responsible, in broad terms, for the red end of the spectrum, a second for the blue end, the third for the middle or green part, and that the stimulation in greater or less proportion of these

three gives rise to the varied colour sensations which the eye can afford. We may say at once that the theory is entirely satisfactory in describing the chief features of colour-matching and colour-mixture; in fact it was largely put forward as a physical account of these phenomena. For describing the make-up of light of any colour in terms of coefficients based on three primary colours it is of the highest value, a value which must remain, whatever view we take of the mechanisms of the visual organs.

But as a physiological theory of the activities of these organs it presents many difficulties. In the first place the comparatively symmetrical visibility curve carries no suggestion that it is really built up of three primary component curves in anything more than a formal analytical sense. When we observe the extreme asymmetry of the supposed three components, and the fact that the "blue" curve is so much smaller than the other two as to need plotting on a greatly magnified scale, the view that these curves have a real physical significance becomes even less convincing. Further, I have just shown you that the complete visibility curve can be accounted for accurately by a theory which in no way requires any triplicity in the eye.

There are other difficulties, even more direct and serious. If there are three mechanisms, the triplicity cannot be confined to the retina alone. As Guild has remarked, the visual cortex must likewise have a threefold mechanism, since distinct reactions in the retina for, say, red and blue lights would be of no avail unless there was a receiving differentiation at the cortical end. We must add to this the further difficulty that the triplicity must also somehow be preserved in the action currents in the fibres of the optic nerve and tract; identical signals passing along a telephone wire cannot give rise to different responses at the receiver.

When we come to think out the sort of differences which can exist in the retina, our path is still far from easy. There might be three sorts of cone, for red, green and blue. In this case only a fraction, of the order of one third of the whole number, would come into play when the exciting light was red, while the whole number would respond to white light, a mixture of the three primary colours. Now the acuity of the eye, its

power to distinguish apart neighbouring bright points on a dark background, for instance, must depend on the closeness of packing of the cones of the retina. We should then expect acuity in red light to be perceptibly worse than in white; actually, with equal brightnesses, acuity in monochromatic light is as good as in white light.

If we reject three types of cones, we may suppose that there are elements in a single cone which respond differently for red, green and blue lights We do in fact know that retinæ of different animals contain a considerable number of different photo-sensitive substances: the most familiar is the visual purple of the rods, but there is little doubt that allied, or at any rate similarly photo-sensitive, materials are also associated with cone vision, that responsible for our perception of colours. But there is no clear evidence of the existence in a given retina of three sharply distinguished substances of the kind required. One ought perhaps to except the results of brilliant researches by Ragnar Granit and his colleagues, which make a strong case for elements which do respond differentially to lights of different wavelengths. He regards his findings as supporting the trichromatic theory, but his "green" elements show considerable variation among themselves, and the same is true of the "red" and "blue" elements, the longest green is not far removed from the shortest red, nor the shortest green from the longest blue. He also records that the type of reaction of a given element depends a good deal on the state of light adaptation of the eye at the time of observation, and further that he has never found an element which conforms to one type under all such variations of adaptation. It is, I think, fair to conclude that his work, while clearly showing the existence of elements of varied response, makes a less convincing case for three sharply differentiated classes. But even definite evidence of this would in no way lessen the difficulties as to visual cortex and nerve fibre.

For the action currents in these fibres these difficulties are perhaps even greater: how can such currents, consisting of packets of negativity following each other in a rhythm of frequency controlled by the intensity of the stimulus give us the threefold differentiation the trichromatic theory demands?

To postulate three different kinds of discharge in a fibre, each maintaining its individuality, representing the relative contributions of the red, green and blue primaries, is to ask too much of any living tissue.

If we examine the basis on which the three-component theory rests, the equation of a colour-match, it also proves to be somewhat insecure. I can make this clear by an example. We can match any colour by a suitable mixture of the three primaries: that is the fundamental fact of colour matching. If we adopt three real primaries, i.e., light of three definite wavelengths in the red, green and blue parts respectively of the spectrum, and use them to match a fourth wavelength, the colour equation is always of the same form. I will take the case of a match of $0{\cdot}5\mu$ wavelength by the three primaries, $0{\cdot}65\mu$ (red), $0{\cdot}353\mu$(green), and $0{\cdot}46\mu$ (blue), used by W. D. Wright in his admirable "Redetermination of the Trichromatic Coefficients," published as a report of the Medical Research Council.

The equation is: $1\ (.5) = -{\cdot}233$ Red $+ {\cdot}772$ Green $+ {\cdot}461$ Blue. I call your attention to the negative sign. Of course light cannot be negative in amount: what the equation means is that to match the light of intensity 1 and wavelength $0{\cdot}5\mu$ by ·772 of the green primary and ·461 of the blue primary you must add ·233 of the red primary to the $0{\cdot}5\mu$ light. In other words the colour equation is really

$$1\ (.5) + {\cdot}233 \text{ Red} = {\cdot}772 \text{ Green} + {\cdot}461 \text{ Blue}.$$

No matter what colour in the spectrum is chosen, the matching equation is always of this type: a particular mixture of two primaries matches a mixture of the third primary with the given colour. I think you will agree that very little triplicity is left in such equations. Which primary has to be brought over to the credit side depends on the selected non-primary spectral colour, but this is always the type of equation. It represents a perfect match: the brightnesses are equal, 1·233 on each side in the example taken: the tints are identical.

It is clear that two conditions have to be fulfilled, the equality of brightness and the match of colour. The first condition, in the terms of my hypothesis, is that the receptor energies of the two lights must be equal. What is the second condition?

Brightness, that is what we may term quantity of response, is determined by the totality of action current or of receptor energy. The difference which decides change of colour must lie in the make-up of the individual packets of action current, i.e., in the group of electrons which constitutes its charge. These electrons owe their origin to the arrival of quanta of light-energy in the stimulating illumination. The all-or-none law assures us of the equality of energy of the several packets; their difference must lie in the number of electrons and their individual energy contributions. The smaller their individual energies the greater must be their number to produce the same total energy in the packet. Now red light has smaller quanta than those corresponding to other colours, the quantum $h\nu$ increasing as we pass along the spectrum towards the violet end, i.e., to waves of ever-increasing frequency ν. May not this change be responsible for the variations within the packets, the larger number of electrons making up the packet under stimulation by red light, the smaller under stimulation by blue, with graded transition from the one extreme to the other as we pass along the spectrum? The final discharges at the visual cortex will thus also differ according to the wavelength of light and so provide the clue for the changing colour-sensation.

We can carry the inquiry further by writing down the expressions for the components of receptor energy in a mixed stimulus due to light of different wavelengths. If for example we take the colour match whose equation I have quoted, the first equation, for equality of brightness, is $S_\lambda = S_r + S_g + S_b$, one of the primary components being negative.

This is the equation for the energy as a whole; it tells us that the total is the same for the two matched lights and that therefore the rhythm rates of the two action currents must be the same, since the all-or-none law holds.

Now the energy S_λ is made up of the energy of a number of electrons, each due to the arrival of a quantum of light of wavelength λ, of energy $h\nu$. The number of quanta is then $S_\lambda/h\nu$ and this is also the number of contributing electrons per second and therefore proportional to the number per packet. In this we assume that the electron carries all the energy of its generating quantum; in fact some energy is lost in freeing it

from the molecular constraints, and if we adopt the usual photo-electric relation, the energy with which it emerges is $h\nu - c$, where c is the lost energy. Hence the efficiency of the transaction is $(h\nu - c)/h\nu$ or $1 - c/h\nu$, which we may write $1 - k\lambda$, since ν is inversely proportional to λ.

So, returning to our colour match, the equation for equality of average energy per packet in the two lights is made up of terms such as $S_\lambda \lambda(1 - k\lambda)$, again using λ instead of the reciprocal of ν.

The colour match equation is therefore

$$S_\lambda \lambda(1-k\lambda) = S_r\lambda_r(1-k\lambda_r) + S_g\lambda_g(1-k\lambda_g) + S_b\lambda_b(1-k\lambda_b),$$

one of the primary component terms on the right hand side being negative as before.

The data of Wright's Report give us all we require to test this relation. His results are expressed in the units known as trichromatic coefficients, and to convert them into luminosities each primary component term must be multiplied by a certain factor. Dr. Wright has been good enough to supply me with these three factors for his primaries, and I have recalculated, in terms of luminosities, his Table I, which defines the conditions of colour matches for 25 wavelengths through the spectrum. This recalculated table is shown in Table 2, in which for clearness I have only included a few wavelengths. These figures are the S's of our equations. The intensity equality of course appears in each line; there is nothing new in this.

Table 3 shows the further calculations for the selected colours. The products $S_\lambda \lambda(1-k\lambda)$, and the three similar expressions for the primaries are given. They are quantities proportional to the amounts of energy carried by action current packets owing their origin to the wavelength λ and the matching three primaries. For a colour match, then, the value for the matched light should be equal to the sum for the three primaries. It will be seen that this agreement is found: it is equally satisfactory for all the 25 wavelengths whose data Wright's table allows us to test.

We thus have a physical equation expressing the condition that two illuminations should match in colour; the earlier equation was that for a match in brightness. The two give a unique specification of a complete match.

The particular colour sensation evoked by light of a given wavelength hence depends on the number of electrons concerned in building up the invariable energy of an action current packet. Change of strength of the stimulus without change of wavelength changes the rhythm of the current and thereby the brightness perceived, but in no way effects the individual packets, so the colour remains unaltered.

On the other hand change of the stimulating wavelength, even though the stimulus is such as to produce the same brightness as before, results in a change in the electronic make-up of each energy packet, and therefore in a change of colour.

The brightness factor is the total receptor energy, the colour factor the constitution of the action current packets. The former, as we saw, varies with wavelength throughout the spectrum, for constant energy supply giving the visibility curve. The latter depends on the magnitude of the quantum for the particular wavelength, and so also on an expression which varies continuously throughout the spectrum. There is no need for any triplicity of mechanism anywhere in the organs of vision.

TABLE I.

Visibility (observed)	Wavelengths λ_1	Wavelengths λ_2	Geom. Mean $\sqrt{\lambda_1 \lambda_2}$	Visibility (calculated) Weber-Fechner range.	Visibility (calculated) Low visibility range.
1	·556		·556	1	—
·952	·542	·570	·556	·951	—
·870	·533	·580	·556	·865	—
·757	·524	·590	·556	·752	—
·631	·5185	·600	·558	·639	—
·503	·510	·610	·558	·503	—
·380	·504	·620	·559	·378	—
·262	·496	·630	·559	·236	·262
·170	·486	·640	·558	·071	·171
·103	·474	·650	·555	—	·103
·059	·460	·660	·551	—	·061
·030	·446	·670	·547	—	·030
·016	·434	·680	·543	—	·016
·008	·425	·690	·542	—	·009

TABLE 2.

Wavelength (μ)	Component Luminosities S_r	S_g	S_b	Total ($= S_\lambda$)
0·41	·025	−·058	·054	·021
·45	·010	−·030	·054	·034
·50	−·113	·950	·025	·862
·55	·113	·980	−·002	1·091
·60	·113	·241	−·000	·635
·63	·470	·046	−·000	·516
·68	·491	−·014	—	·477

TABLE 3.

Wavelength (μ)	Component Products $S_r\lambda_r(1-k\lambda_r)$	$S_g\lambda_g(1-k\lambda_g)$	$S_b\lambda_b(1-k\lambda_b)$	Sum	Product for λ $S_\lambda\lambda(1-k\lambda)$
0·41	·0083	−·0185	·0163	·0060	·0060
·45	·0033	−·0096	·0164	·0101	·0101
·50	−·0376	·3033	·0075	·2732	·2695
55	·0376	·3129	−·0005	·3500	·3524
·60	·1312	·0769	−·0001	·2080	·2095
·63	·1565	·0147	−·0001	·1711	·1714
·68	·1635	−·0045	—	·1590	·1590

($k = 0·75$)

Historical Method in Teaching Science.

By J. KENNER.

The teaching of Science has previously engaged the attention of this Society, for it was the subject of an Address in 1928 by Professor W. L. (now Sir Lawrence) Bragg, in which he discussed the matter on its own merits, emphasising the difference between the merely learned and the able man, and suggesting that it was the latter type we should endeavour to produce. He did not, however, make any particular suggestion as to how this might best be done beyond pointing to the value of a habit of thought based on general principles rather than on masses of facts, and to the harm which the burden of these latter may inflict on the student.

On this occasion I will hope to carry the matter somewhat further, approaching it from the wider standpoint of the problem of Education in general. This is to-day the subject of much uneasiness and attention, and the symptoms which give rise to the uneasiness are, I think, fairly illustrated by the following quotations from the Press of recent months .—

The Times, in a leading article on the disasters in the Far East, wrote : " . . . It would be an irresponsible and superficial judgment which ignored any longer the thread running through the whole series of defeats and leading back to the root causes of them all. . . . Considered in the broadest terms, the causes of our failure may be reduced to two : lack of imagination and lack of capacity to innovate. And these two causes are themselves interwoven. . . . The causes of failure lie deeper than any individual incompetence ; they lie in the inadequacy of a whole outlook, a whole method of approach."

Another writer in *The Times*, in August, 1942, wrote : " Nothing illustrated more vividly the blind spot of British Administration in the Far East than a visit direct from a British colony, to one of the missionary settlements in China. The change in the mental climate was startling. Here were men working enthusiastically for great ends, whose every action, however dull and repetitive, was inspired by devotion to the shining goal they saw ahead. The routine of the civil service was illumined by no such radiance. The ability, the integrity, and the energy were there, but not the inspiration."

In connection with youthful delinquency, The Lord Mayor of Manchester, Alderman Wright Robinson, was reported by the

Manchester Guardian to have said : " What boys often lacked was a feeling of personal significance, and many of the things they did were adventures undertaken to draw attention to themselves. Though I don't quite know how we are going to do it, we have got to make the younger generation feel that what they are and what they do matter to the community. . . . Youth finds itself driven by a great big new dynamo ; it doesn't understand what it is, but it has to respond to it whether it likes it or not, and if we have to harness this energy it must be to an outlet which youth itself believes worth while."

To these I would add that the fact that none of these various shortcomings was traced by its commentator to its origin constitutes a further symptom.

Turning now to the purveyors of Education, we have the following recent statement by the Headmaster of Winchester College, writing to *The Times* as Chairman of the Headmasters' Conference : " For many years past headmasters have been conscious of the difficulty of maintaining the study of ' general ' as opposed to ' technical ' subjects, in the face of the growing encroachment of technology on school work. . . . All this constitutes a real threat to the depth and balance of English education." In my view, a fundamental error in educational outlook is here revealed. A balance is an instrument by which the weight of one object is, to use Canon Leeson's word, " opposed " to that of another, for purposes of either comparison or restraint, but I suggest this is a false view of the relationship of Arts and Sciences in Education, and that they are complementary and co-operative rather than alternative or competitive. If this be so, an educational scheme in which either is not included is clearly incomplete, and in devising a satisfactory scheme we have to assign to each its due place.

We can, however, only do this after we have determined the essential characteristics of the whole structure our scheme is to be designed to build. It is, I believe, a failure in this determination which is the root cause of educational difficulties. The Sub-Committee of the Science Masters' Association, in its Report on the Teaching of General Science, refers to Sir Richard Gregory's definition of education as the deliberate adjustment of a growing human organism to its environment, and states that

its proposed course of General Science "is designed to enable boys to take an intelligent view of many aspects of their environment." The failure to which I refer is the failure to recognise that if this environment is to be healthy it must be progressive. I find no hint of this in Plato's conception of Education, as set out in Sir Richard Livingstone's "Selections from Plato," and I venture to think it was in consequence of this deficiency that Greek authority in the world was eventually undermined by a vicious decadence and passed away.

Education, then, should be conceived and designed as a training for life in a progressive environment, and for fulfilment of the duty of contributing, each according to his ability, to its progress. The interest so usually aroused in the young by stories of exploration and invention is, I think, evidence of the aspiration implanted in us to make this contribution. The task of educationalists would then be the wise evocation and nurture of this aspiration, by the clear indication of the rôle of each item in the curriculum, and by its correspondingly appropriate presentation, as a factor contributory to fulfilment of the purpose of Life.

In the scheme thus conceived religious training would have an essential place as providing the principles of moral and ethical progress; history and literature would be presented as the record and discussion of Man's application or non-application of these principles in the past, and of the results which ensued, whilst Natural Science would appear as the record and instrument of progress on the material side. Here, I think, is the solution of what Messrs. Humby and James in their recent book, "Science and Education," describe as "one of the deepest problems of present-day education, the need for unification, for building some bridge across the gulf which separates literary and scientific studies."

I suggest that if "such a creative and forward-looking spirit," as the recent Nuffield College statement on Industry and Education terms it, had permeated our Education in the past, the difficulties and failures represented by the quotations I cited at the outset would either have been much mitigated or not arisen; there would have been no need for proposals to tack courses in Citizenship on to a defective educational conception; a Bishop

of Ripon would not have suggested the desirability of a Holiday from Scientific Progress; Sir Richard Livingstone could not have stated, as he has done in his book, "The Future in Education," that Science is not concerned with the supreme ends of Life; and Canon Leeson would not have written as he did.

"Manners makyth Man," which has been the essential *motif* of education not only at Winchester College, but also at many of our leading Schools, no doubt admirably expresses that mere Hellenic, as contrasted with the Christian, conception, which is too often the basis of the "character" so persistently commended to us as the ideal equipment for Life. It does represent an essential ingredient of Education, but is in itself inadequate, since it may conduce to, and indeed, as I believe, is largely responsible for, that merely static view of citizenship which is the origin of many of our troubles. In this connection we may recall that whilst the Greeks devised various scientific theories, the idea of actively testing these by experiment had to await the advent of Roger Bacon. In our own day, Mr. Guedalla has written in his recent Life of Mr. Churchill that in 1923 "ability had been discarded as a test of public men in favour of a more passive quality ambiguously defined as 'character.' For ability might lead to enterprise, enterprise to action; and who knew what might happen then?" How curiously apt is this as a commentary on the deficiencies noted in the extracts of *The Times* quoted at the outset of this discussion! Is this static conception not also the source of what Sir Stafford Cripps latterly termed "a lack of a sense of urgency" in our life, and which has been patent to any observer for many years?

In the framework of our more dynamic conception we shall be primarily concerned in the teaching of Natural Science to present a record of progress, and of the methods by which this has been achieved. We shall therefore regard as fundamentally misconceived the practice, which still survives in some Universities and is advocated anew from time to time, of giving separate Courses on the History of Science, and shall realise that this must constitute an integral part of our teaching. We shall be wise to acquire the material for our courses not, as is frequently the case, at thousandth hand from text-books with a corresponding risk of distortion, but as directly as possible

from the original literature. In selected instances, this should be placed in the hands of pupils. Certainly in Chemistry, excellent material of this kind concerned with the elements of present-day Science, and thus well adapted for School teaching, is available, e.g., in reprints by the Alembic Club and in the translated edition of Scheele's papers, published by Messrs. Bell. Such papers, emanating from the early workers, are usually detailed both in exposition of the development of motive and thought and in accounts of experimental method, and so can serve to equip the future citizen with an appreciation of Science, its discipline, its procedure, and its possibilities, which will be useful not only intrinsically but also as a criterion of proposed public policy in regard to it.

I would particularly emphasise the importance of this latter aspect of the matter. Owing to lack of understanding in this direction on the part of well-meaning and public-spirited civic administrators, and of those responsible for the direction of industry, this country has suffered in the past incalculable frustration and damage. And this is likely to continue unless our teaching is so directed as to impart to all, and therefore necessarily at school, a properly informed appreciation of the fundamental issues. Quite recently the Federation of British Industries, as reported in *The Times*, has affected to deliver what will be regarded as a weighty and responsible pronouncement on the problem of the Public Schools, in the course of which it states: "The school curriculum adequately covers the natural sciences, but in general devotes much less attention to the mechanical sciences, and to this extent fails to provide an adequate introduction to an extensive range of industry." As though the so-called "Mechanical Sciences" were anything but particular applications of the Natural Science of Physics! This provides both a measure of the affectation and an instance of the danger to which I refer. Again, how else than with the aid of such training as I advocate can the citizen rightly gauge what is prudent and what imprudent in the "Planning of Science," of which we are hearing so much to-day?

Those pupils with any degree of aptitude for Science will also receive from a well-considered historical treatment the best form of stimulus to further study, and, if this should lead them

to a University, their preparation will be found to have been more valuable than would have been derived from one more factual in character, though possibly somewhat wider in scope. In the sense of my opening paragraph, they will be able students.

It must in fairness be recognised, however, that under present conditions a teacher desirous of giving effect to these suggestions may encounter two difficulties, in respect of which suitable measures would be required. The first is that of the examination requirement, which is such a determining factor in shaping school curricula. Secondly, he is likely to find current textbooks of little assistance. Similarly, since the subject matter of his relevant University courses will have been concerned with the more advanced portions of the subject, they also, whilst providing valuable guidance for elementary teaching in respect of proportion and perspective, will prove to be of little direct help. There is in fact scope, indeed I would say a real need, for radical reform in this direction in the arrangements made for the training of future teachers. A proper attempt should be made to equip them with material of direct use for School teaching, and preferably by co-operation of the Department of Education with the relevant University Departments. These latter would on their side benefit from such an arrangement, because it would render possible a closer co-ordination of School and University teaching than exists at present.

I have already indicated my view that University courses also must concern themselves not only with the systematic study of knowledge but also with the manner in which this has been acquired. It is true that some direct experience in this matter will be gained by the small minority who later enjoy a training in research, but this will normally be only limited in character, and in any case few University teachers would be sufficiently bold to maintain that an experience, admittedly intimate but probably brief, of their methods and modes of thought is likely to compensate adequately for ignorance of those of the great workers of the past.

In order to illustrate the application of the above ideas to School teaching, an account was given of the discovery of Prussian Blue, and the consequent scientific studies of Scheele, Gay Lussac, and Wöhler, culminating in the synthesis of urea.

English Romantic Poets and Landscape Painting

Sir Kenneth Clark, K.C.B.

The English are a profoundly poetical people, and to an eye trained on French and Italian models it may seem that English painting often degenerates into mere illustration, a by-product of our genius for literature. But this is not true of the great period of spiritual activity which lasts roughly from 1797 to 1837, which begins with the Lyrical Ballads of Wordsworth and ends with the earlier volumes of Tennyson, which begins with the first works of Turner and ends with the death of Constable. During these years painting did not illustrate poetry, but pursued an independent parallel existence in which striking similarities of style, substance and philosophic outlook were largely unconscious and at the time were hardly noticed. This evening I am going to point out these similarities, and I hope thereby to add something to our understanding of both the arts and of the philosophic background which they reflected. Even if I fail in this ambitious purpose I shall at least have had the pleasure of recalling to your memories some beautiful passages of verse and some masterpieces of English painting.

Our survey must begin by noticing two words which flowed with ease and complacency from the pens of eighteenth-century critics, *nature* and the *picturesque*. The scientific thought of the seventeenth century, which had led to a conception of a universe governed by the laws of cause and effect, had given a new meaning to the word 'nature', one of the most curious of the sixty-eight different meanings this unfortunate word has supported.

> "Nature and Nature's laws lay hid in night
> God said *Let Newton be*—and there was light."

Pope's chief claim for himself was that he had led poetry back to Nature, and under his influence the word came to mean little more than commonsense—that which fitted in with a reasonable man's experience. From this it followed that appearances could not be accepted as nature until they had been put in order by the human reason. The same notion was supported by the word *picturesque*, which implied that only certain well-recognised parts of a scene were suitable for inclusion in a

picture. The art of landscape painting, therefore, consisted in selecting such ingredients as had, through long association with classical literature and painting, achieved the character of art; and arranging these ingredients in an orderly, that is to say, a natural manner. Only thus could an inferior branch of painting aspire to that ideal condition which was the philosophic justification of all the arts.

Under such circumstances the connection between poetry and landscape painting in the early eighteenth century was close—" ut pictura poesis erit," said the classic injunction in de Fresnoy's *de Arte Graphica*, " simulisque poesi sit pictura "; but it was an external, or mechanical, connection, an interchange of stage properties rather than an identity of spirit. Dyer, Mallet, West, Akenside and Blair drew their descriptions of landscape from Claude, Salvator Rosa and Berchem; and Lambert, with a number of other forgotten English landscape painters, furnished their pictures from the descriptions of the poets; so that the desire to give an ideal basis to landscape led to a vicious spiral of unreality.

But in addition to these purely superficial resemblances, there were, between the finer poets and painters of the century, certain true similarities of vision. The picture of rustic life in Gray's *Elegy* is artificial, but it is not unreal; it is the result of sincere contemplation by a mind so elegant and discriminating that natural roughnesses are hardly perceived. Exactly the same is true of Gainsborough. He knew country life well, better no doubt than Gray; but his grace of hand and mind made it impossible for him to call a spade a spade. For him the village children who ran to lisp their sire's return, or climb his knees the envied kiss to share arranged themselves naturally in groups as elegant as Gray's diction; and when he sat down to draw cows, his pencil instinctively traced a visual equivalent to " the lowing herd winds slowly o'er the lea." Identity of spirit enhances; similarity of subject may degrade. To read the *Elegy* in front of the canvases of Gainsborough heightens our pleasure in both; but the same lines repeated before the rustic scenes of Morland and Westall merely make us suspicious of Gray, for we recognise that these painters were exploiting Rousseauism and hoping, like Greuze, to captivate the rich;

by removing from their minds any doubt they may have felt as to the charming and contented existences of the poor. If we resist such superficial comparisons there is only one other painter of the eighteenth century whose work concerns us—Richard Wilson. In the composition of his pictures Wilson never discarded the picturesque. It was to him what classic diction was to Gray and Collins. But one thing transformed his vision and gave it a quality which still touches us: his feeling for light and atmosphere A misty valley, a translucent sky, light reflected from water, really touched his heart, and in his determination to render them he sometimes forgot Gray's diction, that "the language of the age is never the language of poetry", he almost told the truth about what he saw; in consequence he almost starved. Now this same sensibility to atmosphere suffuses what is, in form, one of the most classical poems in English—Collins's *Ode to Evening* :—

> "Then lead, calm votaress, where some sheety lake
> Cheers the lone heath, or some time-hallow'd pile,
> Or upland fallows grey
> Reflect its last cool gleam.
>
> Or if chill blustering winds, or driving rain,
> Prevent my willing feet, be mine the hut
> That from the mountain's side
> Views wilds and swelling floods,
>
> And hamlets brown, and dim-discover'd spires,
> And hears their simple bell, and marks o'er all
> The dewy fingers draw
> The gradual dusky veil."

Nor is this an isolated instance, for in many of the formalised poems and pictures of the Augustan age we are suddenly touched by a quality of light, which gives to the orderly, man-made scene some colour of the incomprehensible.

"Fine landscape" says Stendhal in his *Mémoires d'un Touriste,* "is no less essential to an Englishman's religion than to his aristocratic station." In the eighteenth century the second half of this proposition was true, and landscape painting, even when not directly concerned with the portraiture

of gentlemen's parks, was treated as an adornment of aristocratic life. It was during the ten years from 1795 to 1805 that landscape became a religion. The story of how this happened is familiar to you. You will remember how Wordsworth returned from France disillusioned with mankind and only half convinced by his own revolutionary ardour: how he tried to comfort himself with the humanitarian theories of Godwin, and how, in despair at these barren abstractions (and was ever a man more desperate than the author of the *Borderers*) he turned to the passive contemplation of landscape. He was led to do so by a deep instinct, half recognised, as the *Prelude* tells us, in his youth; and when this instinct turned out to be true, when the simple contemplation of skies and flowers not only restored the balance of his mind but gave his spirit unexampled creative energy, he was moved to see in these phenomena the divine power which he had sought in vain among the theories of his fellow men. Nature, then, ceased to be a mechanical universe working under the dictates of commonsense—"an old eight-day clock," as Carlyle called it, but became all that part of the world which is not created by man and which can be perceived through the senses. And the old struggle between matter and form was at an end: there was enough of the divine in pure nature for us to receive it gratefully without attempting to refashion it in our minds.

How far Wordsworth, left to himself, would have expanded this personal revelation into a philosophy is uncertain; but in 1795 began his intimacy with a man whose mind was the perfect complement to his own—Coleridge. Writing after they had separated, Coleridge criticised Wordsworth for too great matter-of-factness; his own mind, as we know, was a melting pot of curious fancies and fragments of useless but enchanting information, stirred round by the relentless spoon of philosophy. Given one fixed point, one fundamental conviction, he could see the most insignificant fact in its general bearing; and this conviction Wordsworth provided.

The repetition of these familiar facts may seem to have led us rather far from painting, until we remember that at this date Coleridge's philosophy was dominated by the system of David Hartley. Now Hartley's doctrines of sensation and association

underlies modern painting and separates it from the intellectual and platonic approach of preceding centuries

During the same decade in which Wordsworth and Coleridge were discovering a new way of looking at Nature a parallel discovery was being made by two young painters Girtin and Turner The fact that both Turner and the Wordsworths visited Tintern in 1793 is a pleasing coincidence no higher claim can be made for it because at that time Turner's style had not yet evolved far beyond its picturesque origins and was almost as full of tags as Wordsworth's *Descriptive Sketches* published in the same year But by 1798 when Wordsworth had revisited Tintern and written his immortal lines Girtin had begun to express in paint some of Wordsworth's direct delight in nature and Turner had exhibited in the Royal Academy a painting of Buttermere which actually anticipates the vision of the Lake school of poetry Turner, as I hope to make clear later, was essentially un-Wordsworthian and only painted one picture the 'Frosty Morning in which the approach to nature is humble and passive but Girtin had just those pure responses which his talented companion lacked Like Wordsworth he could have said

' The sounding cataract
Haunted me like a passion the tall rock
The mountain and the deep and gloomy wood,
Their colours and their forms were then to me
An appetite , a feeling and a love,
That had no need of a remoter charm,
By thought supplied, nor any interest
Unborrowed from the eye "

It is the last lines which are important Painters of the eighteenth century—Cozens for example—had felt the poetry of the sounding cataract and the deep and gloomy wood but they had all believed that landscape required the " remoter charm by thought supplied," and that without " some interest unborrowed from the eye " it would simply fail to be art To Girtin the simple beauty of the thing seen, the mere play of light on roof, street or river was enough He believed, in Wordsworth's words, that " the human mind is capable of being excited without the application of gross and violent stimulants " His scenes of

moor and mountain are grave and simple. Buildings delighted his eye as much as wild nature; and I can never look at his townscapes without thinking of the passage in Dorothy Wordsworth's *Journal* in which she described the view from Westminster Bridge when she and her brother were leaving for France on the early morning of July 31st, 1802. "The houses were not overhung by their cloud of smoke, and they were spread out endlessly; yet the scene shone so brightly . . . that there was even something like the purity of one of nature's own grand spectacles." Her brother's reflections on the same occasion will be familiar to you. A few months later Girtin painted his last pictures of London and died.

But in spite of the close similarity of these transparent visions, Girtin is only the beginning of Wordsworth. The very lines I have quoted to justify my original comparison refer back to Wordsworth's first visit to Tintern in 1793, and are introduced by the words: "I cannot paint what then I was." By 1798 this passive contemplation, though still the basis and, as it were, the ritual of his religion, was only the prelude to

> " . . . a sense sublime
> Of something far more deeply interfused,
> Whose dwelling is the light of setting suns,
> And the round ocean and the living air,
> And the blue sky, and in the mind of man:
> A motion and a spirit that impels
> All thinking things, all objects of all thought
> And rolls through all things."

Such a "sense sublime" Girtin generally lacked. He might well have developed it, just as Wordsworth did, had he lived beyond the age of 27. At that age John Constable (who was only a year younger than Girtin and Turner) was still painting in a style so tentative that only the most subtle critic could have foreseen in him the power to carry Girtin's style to its full Wordsworthian conclusion.

There are hints of Wilson in the early Constable, and distant traces of the Dutch. But considering the importance then attached to style, the directness of his work and its freedom from the platitudes of the picturesque constitutes one of the

wonders of art history. To recognise the force of his originality one must remember that in his student days the formidable Fuseli had referred, in his lectures, to that "last branch of uninteresting subjects, that kind of landscape which is entirely occupied with the tame delineation of a given spot." Constable's independence was bought at the price of a slow and fumbling start. In 1802 he succeeded in having a picture exhibited in the Royal Adacemy; and in the same year Turner, who had successfully mastered every trick of the trade, was made a full Academician. It is not till about 1809, in such a picture as the "Malvern Hall," that we feel a sense of perfect confidence; and in it he is clearly the heir of Girtin. But already in sketches we can find evidence that Constable is brooding on "the motion and the spirit that rolls through all things." And indeed the very stubbornness with which he drives direct at nature is truly Wordsworthian. Constable never had the least doubt that nature meant the visible world of tree, flower, river, field and sky exactly as they present themselves to the senses; and he seems to have arrived instinctively at Wordsworth's conviction, that by dwelling with absolute truth on natural objects he would inevitably reveal some of the moral grandeur of the universe. It is to this end that he painfully evolved a more vivid pictorial language, throwing over all the stylistic equivalents of his predecessors; and to this end he refuses, from "Malvern Hall" onwards, to paint the park scenery beloved of the early English landscape painters, and chooses episodes of humble and rustic life: because, to quote from Wordsworth's *Preface* of 1802, "in that condition our elementary feelings co-exist in a state of greater simplicity, and consequently may be more accurately contemplated and more forcibly communicated."

"I never saw," said Constable, "an ugly thing in my life." His belief in the divinity of nature was founded on a passion and an appetite. "I have seen him," says Leslie, "admire a fine tree with an ecstasy of delight like that with which he would catch up a beautiful child in his arms." We are reminded of Henry More, the seventeenth century platonist, of whom his biographer tells us "that walking abroad after his studies, his sallies towards Nature would often be unexpressibly enravishing, and beyond what he could convey to others."

Wordsworth's kinship with this mood of the seventeenth century, with Vaughan's celestial infancy, with Traherne's rapture over the fields of corn, and even with Isaak Walton's quiet joy in the small incidents of nature, has often been pointed out. The mood survived into the mechanistic world of Newton and Pope, and is to be found glowing more faintly in Cowper's letters and White's *Selborne*. "I have," said Constable in 1812, "all Cowper's works on my table. I mostly read his letters. He is an author I prefer to almost any other." And of White he writes: "The mind that produced *Selborne* is such a one as I have always envied A single page of the life of Mr. White leaves a more lasting impression on my mind than all that has been written of Charles V." This love of particularity—this doctrine of the microcosm is entirely opposed to the classical notion of poetry. "The business of the poet," says Imlac, in Johnson's *Rasselas*, "is to examine not the individual but the species. He does not number the streaks of the tulip or describe the different shades in the verdure of the forest." But to Wordsworth the linnet, the daisy, the glow-worm and the lesser celandine are points of focus on which his mind shines with the intensity of a burning glass, and with the joy of a lover or an explorer. "You never enjoy the world aright," says Traherne, "till the sea itself floweth in your veins, till you are clothed with the heavens, and crowned with the stars; . . . yet further, you never enjoy the world aright, till you so love the beauty of enjoying it that you are covetous and earnest to persuade others to enjoy it." So Wordsworth can persuade us to enjoy a daisy or Constable to enjoy (to quote from one of his letters) "the sound of water escaping from mill dams, willows, old rotten planks, slimy posts and brickwork." How clearly one feels in this catalogue of delightful objects the greedy, rapturous gaze of childhood.

But revealing as Constable's letters are, it is, of course, through his pictures, not through his words, that we can recognise his similarity to Wordsworth; and I hope it is not straining a metaphor to say that this similarity is partly one of diction and partly of vision. Wordsworth's *Preface* lays great stress on the question of poetic diction; too great, as it afterwards turned out, for it has deflected attention from the

main value of that noble confession of faith. Similarly Constable's contemporaries, both admirers and detractors, dwelt chiefly on his unprecedented style. Wordsworth's language, "a selection of the language really used by men," and Constable's absolute directness both seemed crude and inadequate to the expression of great emotions. It is a commonplace of criticism that Wordsworth in his greatest moments used a noble and elevated diction closer to *Paradise Regained* than to common speech. It is equally true that Constable, when painting from "the spontaneous overflow of powerful feelings," abandons naturalism in favour of a highly personal manner, which in his later work ran dangerously near to a new kind of mannerism. Nevertheless this question of language is crucial. There is nothing in the sentiment of Gray's *Elegy* foreign to Wordsworth, nor in the spirit of Wilson foreign to Constable. The cleavage between them is due to the language in which spirit and sentiment are conveyed. There was a real impropriety in the attempt to represent humble life, with its grim, basic realities, in drawing-room language or in drawing-room tints, and it is chiefly through the revolution in language that the new interpreters of nature succeeded in avoiding the false Rousseauism which had enervated the poetry and painting of the late eighteenth century. But we must remember that it was not only the simplicity of Wordsworth's language which worried his contemporaries; it was the violence of his metaphors. They objected that his heart could not possibly dance with the daffodils; and that an old man could not be at one moment like a huge stone, at the next like a sea-beast, and at the next like a cloud. In the same way it was the violence of Constable's transpositions, and not simply his directness, which alarmed his academic colleagues, and would have alarmed them still more had they been familiar with his sketches.

The similarities of vision have been obscured by a simple fact: that Wordsworth wrote chiefly about mountains whereas Constable preferred to paint water meadows. Constable visited the lakes in 1810 and made a number of studies there, both in oil and watercolour; but these are the flattest and most prosaic of all his works—as if his native honesty were in revolt against the exaggerated picturesqueness which most painters found

there. In fact, both men were happy only in the scenes of their childhood, and each has recorded how it was the influence of those scenes on their youthful minds which determined their creative gifts "I should paint my own places best" wrote Constable; "painting is with me but another word for feeling, and I associate 'my careless boyhood' with all that lies on the banks of the Stour; those scenes made me a painter and I am grateful—that is, I had often thought of pictures of them before I ever touched a pencil." Wordsworth's account of the same events I will not quote, as it occupies the first six books of the *Prelude*. Once this barrier to understanding is removed, it is easy to recognise the Wordsworthian element in Constable's vision, both in the intense contemplation of individual plants and trees, in the deep understanding of the weather, and above all in the way in which (to quote Wordsworth's *Preface* again) "the passions of men are incorporated with the beautiful and permanent forms of nature." In such a picture as the "Leaping Horse" the movement of the barges, the weight of the water, the noble doric architecture of the lock are all expressive of man's dignity and determination, just as the sky and agitated trees are expressive of his emotional struggles. They are as much symbols of moral force as the landscapes of the "Leech Gatherer" or the "Old Cumberland Beggar."

That this similarity should have escaped general notice is not surprising, considering that Wordsworth and Constable failed to recognise it themselves. The two must have met with their common patron, Sir George Beaumont, and the painter occasionally quotes the poet and speaks with admiration of the landscapes in the *Excursion*; but the poet was entirely oblivious of the painter. Like all the great writers of his time he seems to have been stupefied by Benjamin Robert Haydon. It is curious that Wordsworth should have expressed admiration for pictures which offend against one of his first laws—that the feeling developed in a work of art should give importance to the action and situation and not the action and situation to the feeling. Perhaps after all Haydon, like several unsuccessful painters since his time, extorted literary tributes from his friends more by the force of a tenacious personality than by direct appeal to the optic nerve. For Hazlitt, who knew both

about Wordsworth and about painting, has left a different account of his tastes —

In art he greatly esteems Bewick's woodcuts and Waterloo's* sylvan etchings. But he sometimes takes a higher tone and gives his mind fair play. We have known him enlarge with a noble intelligence and enthusiasm on Nicolas Poussin's fine landscape compositions, pointing out the unity of design that pervades them, the superintending mind, the imaginative principle that brings all to bear on the same end, and declaring that he would not give a rush for any landscape that did not express the time of day, the climate, the period of the world it was meant to illustrate, or had not this character of wholeness in it. In contrast to this painter-like appreciation we may recall how Constable claimed for one of Poussin's landscapes that 'it was full of moral and religious feeling.' How sad that shortness of focus prevented Wordsworth from enjoying a painter who stood to Poussin in very much the same relationship as he himself stood to Milton.

There is no doubt, I think, that what prevented the poets and prophets of the romantic movement from recognising the greatness of Constable was simply that he didn't paint mountains. Mountains were sublime, and romanticism was rooted in the sublime, and after Wordsworth mountains were moral. There was something ennobling about looking at, and later, about climbing a mountain. Of this, as of so many other unchallenged beliefs of the nineteenth century, the prophet was Ruskin, and it is one of the chief reproaches against that great critic that he failed to appreciate Constable. To have written those five portentous volumes on the theme that absolute truth to nature is the aim of painting and the achievement of modern painters, and to have made therein no more than a passing, disparaging reference to Constable, would astonish us were we less familiar with the workings of Ruskin's mind. We know that this immense apologia was undertaken in a spirit of partisanship which precluded objectivity. It is curious, however, that Ruskin should have sought to justify Turner by Wordsworth, and actually to have placed a quotation

* Waterloo's etchings, now almost forgotten, were also a great influence on Constable.

from Wordsworth on the title page of each volume, when as we now see, Turner's affinities were with the opposite school of romantic poetry.

To the question what qualities in Turner (as opposed to Constable) so effectively captivated Ruskin, we may hazard the following answers. First, his greater range: his determination to seek out and master the most spectacular scenery in Europe. Secondly, a strain of rhetoric: a love of dramatic exaggeration, which Ruskin sometimes criticised in Turner, but which his own style of writing shows to have been near his heart. And thirdly, Ruskin admired the encyclopedic, or pseudo-scientific quality in Turner's approach to nature which was deeply sympathetic with his own aspirations, and which he made the pretext for turning *Modern Painters* from a defence of Turner into a sort of *encyclopedie moralisée* of nature. Now the poets in whom these qualities are to be found are Byron and Shelley, and it is to them, not to Wordsworth, we must turn if we wish to find poetical analogies with Turner.

The comparison with Byron both Ruskin and Turner would have welcomed. Ruskin has told us that Byron's verse was the chief influence on his prose style; and Turner was also influenced directly in choice of subject and imagery. Nevertheless, Turner Byronic is not Turner at his best. The insatiable desire to outshine all rivals, which mars a great part of Turner's mature work, leads him to sink his knowledge of natural appearances in gaudy generalisations. Nature is no longer studied for its own sake, but for what it will yield in immediate dramatic effectiveness. There is, in fact, no better way of conveying the slightly showy and commonplace character of Turner's Italian landscapes than by a descriptive passage—almost any descriptive passage—from "Childe Harolde."

"The tender azure of the unruffled deep
The orange tints that gild the greenest bough,
The torrents that from cliff to valley leap,
The vine on high, the willow branch below
Mixed in one mighty scene, with varied beauty glow."

The images are second-hand (except perhaps for the willow bough, and how Turneresque it is), the diction highly artificial; but the whole has a sweep and brilliancy which Turner never

lost. And it is fair to say that, like Byron, he felt a true sympathy with nature's dangerous moods and had the right to ask of her that he might be

> " A sharer in thy fierce and far delight
> A portion of the tempest, and of thee
> How the lit lake shines, a phosphoric sea
> And the big rain comes dancing to the earth."

We can feel that this is the record of a real experience ; and it was hardly necessary for Byron to add a footnote telling us that he witnessed such a storm on the Lake of Geneva in 1816. Turner, we may notice, painted his first great storms, also from personal observation, in 1812 and 1813 ; and continued to paint them, with increasing joy and freedom, till the end of his life.

The comparison of Turner with Shelley would have pleased neither Ruskin nor the painter himself : and it is indeed extremely strange that two men so dissimilar as the sly old cockney and the fiery, theoretical aristocrat should have had visions of remarkable similarity. Yet who can read such a passage as this without recognising an identity of spirit far more profound than the stylistic similarity with Byron.

> " The point of one white star is quivering still
> Deep in the orange light of widening morn
> Beyond the purple mountains : through a chasm
> Of wind-divided mist the darker lake
> Reflects it : now it wanes : it gleams again
> As the waves fade, and as the burning threads
> Of woven cloud unravel in pale air :
> 'Tis lost ! and through yon peaks of cloud-like snow
> The roseate sunlight quivers : hear I not
> The Aeolian music of her sea-green plumes
> Winnowing the crimson dawn ? "

And who can look at those late works of Turner, where the white canvas seems barely stained by the colours of some unseen spectrum, without being reminded of Shelley ? It is indeed surprising that those who do not like Shelley's poetry have never thought of applying to it Hazlitt's unflattering description of Turner's painting—tinted steam.

The reason for this similarity is not at first sight obvious. But perhaps "tinted steam" gives a clue, for its applicability to Shelley is due not only to its cloudiness, but to a certain suggestion of chemistry—of retorts and test tubes—which it conjures up in the mind. Mr. Geoffrey Grigson, in his recent anthology, *The Romantics*, has emphasised the part played by science in the romantic movement, and has pointed to Goethe and Coleridge as the two great figures in whom the lines of science and mysticism converge. He might have added Shelley, whose less substantial mind was more inclined than that of Coleridge to chemical experiment. Nature to him was not simply to be received through the senses; she was to be analysed, considered in her elements—air, fire, water; considered above all as a function of light. Thus we have come back to Turner, whose study of natural appearances became, as Ruskin pointed out, analytic and encyclopedic; who was led to paint the elements, just as Shelley was led to make them into poetic symbols, and the whole of whose later work may be considered as a series of variations on the theme of light. To this theme I shall return later, since it underlies and unifies my whole subject. I mention it now only to show that, in spite of the difference in their characters, the resemblance between Shelley and Turner is neither fanciful nor accidental, but is necessary to our understanding of romanticism.

Like much else in criticism the comparison of poets and painters may become an after-dinner game. We may find passages in Crabbe which remind us of Crome; poems of Coleridge, "This lime tree bower my prison," for example, which seem to contain the whole spirit of Samuel Palmer. So we may go on, failing only to find a single equivalent to Keats. But for the most part these are no more than pleasant accidents, and add little to our understanding of either subject. I hope that the comparisons I have made this evening are more fundamental, and for that reason I think it worth pressing our enquiry still further, and asking if there was not some common impulse underlying the work of all these great poets and painters during the thirty years of our survey. Casting round for a point of departure, I am reminded of a passage in de Quincey where that wordy apologist of Romanticism says: "Another great

field there is amongst the pomps of nature, which, if Wordsworth did not first notice, he certainly has noticed most circumstantially. I speak of cloud-scenery, of those pageants of sky-built architecture, which sometimes in summer, at noonday, and in all seasons about sunset, arrest or appal the meditative, ' perplexing monarchs ' with the spectacle of armies manœuvring, or deepening the solemnity of evening by towering edifices, that mimic - but which also in mimicking mock - the transitory grandeurs of man." Clouds, it is true, play a part in seventeenth- and eighteenth-century painting, but they are decorative or architectural in intention, marmoreal cumulus which can prolong the curve of a balustrade or set off the angle of a pediment. The changeable, diaphenous and ethereal character of the clouds is seldom attempted. A passage which occurs in one of the MSS. of the *Prelude*, but was excluded from either of the approved versions, describes how, even as a child, Wordsworth began

> " To follow with my eyes the sailing clouds
> In conscious admiration ; loved to watch
> Their shifting colours and their changeful forms "

and

> " Laboured the subtle process to detect
> By which like thoughts within the mind itself
> They rose as if from nothing, and dissolved
> Insensibly."

Thus clouds become a symbol for the instability of the Romantic mind and its longing to float from the solid earth into the shifting splendours of the sky. " The whole mind," says John Foster in his essay on Romanticism, " may become at length something like a hemisphere of cloud scenery, filled with an ever-moving train of changing, melting forms."

I need not labour the importance of clouds to Constable and Turner. " It would be difficult," said the former, " to name a class of landscape in which the sky is not the key-note, the standard of scale and the chief organ of sentiment." With this in mind he made innumerable studies of clouds on the back of which he noted the time of the year and day, and the direction of the wind ; and so attained that familiarity with the logic of the sky which gave him the freedom to use it as an " organ of

sentiment." But although his clouds are very different from the celestial bolsters of the eighteenth century, they are never far from the earth. They are one with his trees and rivers, sprung from the earth and soon to return there in showers of rain. Turner's clouds, as he grows older, become further and further removed into the upper air—nebulous, cirrus, strato-nebulus. No painter before his time had studied the structure of these remote wisps and traceries, and recognised their affinities with shells, crystals and other artifacts of nature on which the elements have imposed a delicate, regular and elaborate design. It took Ruskin many chapters in the first book of *Modern Painters* to explain how true, how significant and how *scientific* were Turner's cloud forms, chapters culminating in what is perhaps the greatest burst of eloquence in all his writings; and even so he felt it necesssary twenty years later in the fifth volume of his immense book to return to the clouds—alas, in a metaphorical as well as in a literal sense.

I have already spoken of the scientific element in Turner and Ruskin, and suggested that it was dominated by the idea of light. Our present point of departure, the romantic love of clouds, leads us in the same direction: for the sky is the source of light, and it is from light alone that the clouds derive their beauty. Light was, indeed, the one gift which Newton bequeathed to the imagination to compensate for the impoverished concept of the mechanistic universe. The problem of light was fundamental to his own studies, just as it was fundamental to Locke's philosophy of sensations. Goethe, the first great poet since Dante to master the science of his time, took the study of light as his chief subject, and to this end drew clouds with the precision and curiosity of Ruskin.

A dominating scientific idea will generally find expression in the arts; inevitably so when that idea strikes at the root of painting. But light had another link with the philosophy of romanticism: its transitoriness, its continuum of change. Light brings into the visual arts the element of time. Perhaps that is why sculpture and architecture—the arts which exist spatially—decayed in the nineteenth century, while music, the art which exists in time, flourished. In the protean struggle of painting with this fluid element Constable and Turner were the pioneers.

"Always remember, Sir," said Benjamin West to the young Constable, "that light and shadow never stand still." Technically the whole of his development may be treated as an attempt to carry out the old painter's advice. Both Turner and Constable were accused, by their more intelligent contemporaries, of sacrificing to effects of light the basic forms which must underlie all visual art. Hazlitt called Turner's pictures "portraits of nothing and very like"; and the French critics are reported by Constable as saying that his pictures "are like the rich preludes in musick, and the full harmonies of the Eolian lyre – which mean nothing." This last opens up a train of thought which could lead us far beyond our subject. For what is the Eolian harp (that prime symbol of romanticism, as Mr. Grigson has called it) but nature herself turned composer —the surrender of the abstract mind in an art where abstraction seemed imperative. By all accounts (for I confess I have never heard one) the harmonies of the Eolian harp must have sounded not unlike the music of Debussy: the music, that is to say, of impressionism, where form is so skilfully overlayed by colour that at first we are only conscious of a shimmering surface. Here, of course, is the answer to the critics: that the principle of unity essential to a work of art, when it could no longer be found in the logical arrangement of the parts, was found in the universal envelope of light, which by its very transitoriness, its continuous movement, imposes its own unifying rhythm.

"And what if all of animated nature
Be but organic harps diversely fram'd,
That tremble into thought, as o'er them sweeps
Plastic and vast, one intellectual breeze,
At once the Soul of each, and God of all?"[1]

* * * *

I said that my survey would end in the 1830's, when Constable died and Tennyson published his first volumes. But to find a pictorial parallel to Tennyson we must extend our researches for at least a decade, and this I shall do, because I believe it will help to clarity the argument I have just put forward. Tennyson, as we all know, was the devoted student of nature. So accurate and graceful were his powers of observa-

[1] Coleridge, *The Eolian Harp*. Composed at Clevedon, Somersetshire, 1795

tion that for almost a hundred years poetry, in the popular mind meant little more than the elegant description of natural appearances. To many it must have seemed that in this he was the heir to Wordsworth; but not to the old poet himself who said of his gifted disciple: "He is not much in sympathy with what I should myself most value in my attempts—the spirituality with which I have endeavoured to invest the material universe." In other words, Tennyson's observations lacked force because they lacked a unifying principle. Now precisely the same is true of the school of painters with which Tennyson is obviously associated, the Pre-Raphaelites. They professed themselves humble admirers of nature and sought with infinite labour to tell the truth about natural appearances. But their work lacked exactly those qualities which Wordsworth admired in Poussin—"the superintending mind, the imaginative principle that brings all to bear on the same end ... the character of wholeness." Their pictures are mere description and so degenerate into illustration or even into frank illustrations without an independent existence of their own. And perhaps the reason is that the Pre-Raphaelites worked outside the main philosophic current of their time—the current which gave universal value to Constable and Turner. They painted natural appearances, but without the vital principle of light, movement or change. It was in France, by the great school of painters known as the Impressionists, that this principle was re-asserted. And I hope I have shown that this school does not simply spring from the vision and technique of Constable and Turner, but has the same basis in science and philosophy. As movements in the history of art and ideas recede opposite factions are generally found to have been on the same side, or perhaps we should say in the same boat. It is pleasant to think of Ruskin and the Impressionists swimming along together, both impelled by the relentless current which flows from Newton to Einstein. Wordsworth himself would have been neither surprised nor displeased at the implications of this movement, of which he was the greatest and most prophetic interpreter. Did he not observe that—"Poetry is the breath and finer spirit of all knowledge; it is the impassioned expression which is the countenance of all science."

The Modern Age in Asia.

By G. F. Hudson, Esq., M.A.

The present war, like that of 1914 18, has begun in Europe and spread to Asia. Thus far history has repeated itself, but if the two wars are compared as they affect Asia, significant contrasts become apparent. There is first of all the great difference in the scale and intensity of warfare in Asia to-day as compared with the struggle of twenty-five years ago. Then Turkey was in the war on the side of Germany and Japan was in it as an ally of Britain. But the total of military operations within the confines of Asia was of small compass in relation to the war as a whole; Turkey was never capable of a great offensive effort and the Allied campaigns against her Asiatic territories were not comparable to the great battles fought in Europe, while in the Far East Japan's belligerent action was in effect limited to the investment and quick capture of a single weakly-held German stronghold. India was not at any time brought directly into the war zone and there was no episode which could remotely be compared to the great sweep of Japanese invasion to Burma and Java involving the conquest of territories with over 100 millions of inhabitants in less than half a year. To-day the war in the Far East and the Pacific is no mere outcrop of the war in Europe but a parallel struggle of similar dimensions.

Along with this difference of scale we can see that much more economic and military power relative to that of European and American nations is now located in Asia than existed there in 1914. Heavy industry was then hardly to be found anywhere in Asia. Japan had built up a strong army and navy, but still remained economically very weak, dependent financially on Britain and the United States. The industrialisation of Russia, such as it was, had not to any appreciable extent reached Siberia or Central Asia. But the last decade has seen the creation of important heavy industrial bases in Japan and Manchuria and in the Asiatic territories of the Soviet Union. Both Japan and Russia, which has become steadily more Asiatic with the eastward movement of its economic centre of gravity, are clearly stronger as measured with Germany, Britain and the United States than they were in 1914. China likewise, although her available war potential is still very small, has become a factor

of organised power in a way she certainly was not at the time when she made her empty declaration of war on Germany in 1917. India is not yet an independent State—or States—but independence has become an immediate issue, which it was not in 1914, and the concern which India causes to Britain and the United States is an indication of her growing importance as a distinct unit in world politics. All this means that Asia has become more of a sphere of independent political and economic activity than she was a generation ago.

More subtle, but nevertheless perceptible, is a change which has taken place in the attitude of Asiatic peoples towards the West, and this is a matter which brings me to what is the main theme of this paper—the relation of these peoples in the present age to Western civilisation. The difference may be described by saying that it is no longer possible, as it was, broadly speaking, a quarter of a century ago, to classify institutions and ideas in Asia into the traditional and indigenous on the one hand and the modern and Western on the other. To-day there is much in Asia that definitely belongs to the modern world, but is specifically Asiatic in substance and not a mere copy or import from the West; there are manifestations of modernity which we may admire or dislike, but which are unmistakably original. Not so long ago the West with its science and technology, its power and wealth derived from continuous economic progress, its administrative technique, its parliamentary democracy and its concepts of municipal and international law, confronted the archaic civilisations of Asia, Islamic, Hindu and Chinese, which materially were on a lower plane and even spiritually seemed to have lost all vitality and creative power. To the intrusions, violent or peaceful, of Western civilisation Asiatics reacted in one or other of two opposite ways; either they resisted uncompromisingly, clinging to the old ways and trying to shut out the hateful foreign influence, or else they broke sharply away from their past and sought in every possible way to acquire for themselves the heritage of the West. After 1900 it was clear that the traditionalists were committed to a losing fight; the dykes were broken, and more and more the new generations were being drawn into the orbit of Western thought and ways of living. Not all Western observers were on the side of their

own civilisation in this conflict; some attributed to the old Asiatic cultures a superior wisdom or spirituality not to be found in the modern West, and many more regretted the passing of what was beautiful, picturesque or romantically attractive in the Eastern scene as they had known it. But they were all agreed that Asia could not in fact remain apart from the modern world and was destined to "westernisation," and they more or less assumed that Asia would become steadily more and more assimilated to the Western world or to some part of it, so that her "progress" could be measured by purely Western standards. In other words, the alternative to traditionalism was conceived as being simply imitation of Western models, and even though the new culture might be combined for a while with elements of the Asiatic inheritance, the latter were regarded as dwindling survivals from the past rather than as roots for new growth.

Western civilisation was, of course, admitted to contain within itself a considerable diversity of type, so that the Oriental pupil was confronted with several different patterns among which to choose. But in the generation before 1914 the common denominator of civilisation in the important Western countries was very substantial, especially if we consider prevailing tendencies rather than established institutions. It may be designated briefly by the word "liberalism" used in its widest sense; it was characteristic of the Anglo-Saxon and Scandinavian countries and of France, and even in Germany it prevailed to an increasing extent. The war of 1914–18, which transformed Germany into a democratic republic and created new States of similar type in Central Europe, seemed for a moment to have completed the triumph of liberalism in the Western world and it was natural to assume that, if the West could speak on essentials with one voice, the East would follow on the same road, especially as all the reforming and modernising movements of the opening years of the twentieth century in Asia had professed a liberal ideology. Already, however, when President Wilson came to Paris to establish the new liberal democratic world order, the West had received a powerful challenge from a country which in relation to Asia had counted as European, but in relation to Europe was Asiatic. The Russian Revolution, beginning as an attempt to set up a Western-style liberal, democratic regime in

Russia, passed on to "Bolshevism" and strove to create an entirely new form of society and culture in complete disregard of Western European sentiment and opinion, whether of bourgeois or of Labour and Social Democrat persuasion.

The mention of Russia in an essay on the recent history of Asia requires some explanation, because the suggestion that Russia is really Asiatic may seem to endorse the Nazi contention that Russia represents an Asiatic menace against which Europe must unite under German leadership. I do not, of course, use the adjective "Asiatic" as a term of reproach, and it is in any case inappropriate for the Nazis thus to use it while they have Japan as their ally. But the Asiatic affinity of Russia is not merely a rhetorical figure of speech. The old Russian Empire, to which the Soviet Union is heir, could be regarded as at least half Asiatic, not merely because the greater part of its territory by area was in Asia, straddling the continent as far as the Bering Strait and the Japan Sea and incorporating peoples of specifically Asiatic traditional culture—the Azerbaijanis, Uzbeks, Turkomans, Kirghiz, Kazaks and Buryats. It was also linked with Asia rather than with Europe in that Russia's early civilisation—and also that of two other peoples of the Empire, the Georgians and Armenians—was derived from Byzantium and did not belong to the Latin Christian tradition from which the modern nations of Western Europe and the Americas trace their spiritual descent. Byzantine culture, though it inherited the Greek language and the Roman imperial system, stood nearer to Asia than to the genuine continuity of Hellenism; it drew its main inspiration from Semitic and Iranian sources and had no share in those late mediaeval developments in Western Europe which produced the decisively original features of our own civilisation. Russia lay outside the range of the Renaissance and the Reformation; cherishing her Byzantine heritage after Constantinople itself had fallen under the sway of the infidel Turk, she took from the devotion of monastic visionaries the doctrine of the Third Rome, according to which Russia alone in the world conserved in temporal independence the true faith of the Christian religion. From this national self-exaltation Russia was violently dragged by the brutal reforming zeal of Peter the Great, who bade the Muscovite nobles cut off their beards and go to school

with the Dutch. Russia thus provided the first large-scale example of what has come to be known as 'westernisation', and her subsequent history affords the most ample field for study of its typical consequences. The transformation of Russia under Peter and his successors was a response to a series of military failures which had dimmed the glory of the Muscovite Tsardom and created an envious admiration for the efficiency of the West. By the Petrine reforms Russia in the eighteenth century became one of the five Great Powers of Europe. But the sudden adoption of what was fundamentally an alien culture set up sharp internal contradictions in Russian life and society. The reforms gave Russia a Western type of law and administration, but they established a form of serfdom more extreme than any Russia had previously known. They gave Russia strength and pride as a national State, but they so denationalised the Russian aristocracy that Yermolov on a visit to the Court of the Tsar could startle the assembly in the antechamber by asking 'Does anyone here speak Russian?' They gave Russia access to all the learning, literature and philosophy of the West, yet they produced a deep dissatisfaction and unrest, a sense of humiliation at having to borrow and become the spiritual debtor of the West instead of being the uniquely favoured land of true religion. This revulsion of feeling was expressed by the Slavophile writers with their disdain of the West and their nostalgia for Slav antiquity and the Orthodox Church, but the Slavophiles could only add to the malaise without being able to put the clock back to their imaginary golden age.

The task set by the Slavophiles—that of freeing Russia from subservience to Western thought as well as from economic dependence on the West—was in the end carried out by men of whom the Slavophiles would most strongly have disapproved—the extreme wing of the Russian Social Democrats who bore the name of Bolsheviks. Superficially the Bolsheviks stood at the opposite pole to Slavophile romantic traditionalism and indeed to nationalism of any kind. Marxism, like the secular absolutism of the eighteenth century and the liberalism which succeeded it, had come into Russia from the West; with its roots in Hegelian philosophy, English economic theory and the French revolutionary tradition, it was essentially a product of

the intellectual life of Western Europe in the middle of the nineteenth century. In accordance with Marxist doctrine the Bolsheviks rated bourgeois democracy as a higher form of society than clerico-feudal monarchy and considered themselves allies of the Russian liberals against the Tsardom and the reactionary Orthodox Church; they also up to 1917 accepted the idea that the more industrialised Western countries stood nearer to socialism than economically backward Russia. But after the November Revolution, and still more after the proclamation of "socialism in one country" in 1925, the fact that Russia had established a socialist regime while Western Europe and America continued to adhere to the capitalist order made Marxism Russia's peculiar possession, in spite of its Western origin. Moreover, in the effort to create the new society the Bolsheviks improvised freely, there being no blueprints from theoretical Marxism adequate for their purpose; soon they began to revise Marxism in the light of their experience and finally claimed an exclusive right of doctrinal interpretation, denying to Western socialist parties and groups any license to speak on the subject. Communism and Russian nationalism thus were reconciled and in the end fused together, not only for world politics but also in the general attitude of Russians towards the West. In the sphere of technology it was admitted that Russia still had leeway to make up and must continue, though to a diminishing extent, to learn from the West. But as regards ultimate values Russia no longer thought of herself as a backward country aspiring to educate herself up to the Western level; on the contrary, she now regarded herself as the *fons et origo* of a new civilisation destined in time to convert the world, the unique pioneer of a form of social life higher than any that existed elsewhere. With every year that the Soviet regime endured and produced concrete results, self-reliance and self-confidence grew. Russia was now once again, in her own estimation—at least in that of the new generation brought up in the Soviet schools—the sole repository of true doctrine in a world of infidels and heretics. Thus she had been also in the sixteenth century, though with a different faith. In this respect the Bolshevik revolution presents a sharp contrast to the changes wrought by Peter the Great. In their material modernisation,

in their violent speeding-up of economic development and crushing of all conservative obstruction, the two epochs have an obvious similarity, and the comparison of Stalin with Peter has received official approval. But Peter did not enable Russia to challenge the West in the field of ideas; he weakened the traditional religious basis of the Russian State without putting in its place anything which Russia could regard as genuinely her own. Lenin and Stalin, on the other hand, have made Russia the homeland of a new religion.

Communism in Russia has all the essential characteristics of a religion and this, far more than its armed force or any merely material benefits it may have conferred, is the secret of its tremendous power. The Communist Party is not a party as the term is understood in a parliamentary democracy nor yet is it a mere faction of politicians for holding office. It is a self-renewing corporation of members bound together by profession of a systematic creed which is a complete theory of the universe and of human life. It comprises nearly all the leading personnel of the State, including the managers of agriculture and industry, the commanders of the armed forces, and also the men who control all education and publicity; it thus performs the functions of a clergy as well as of a military and administrative nobility. And at the head of it stands the man who has been put there by the historical dialectic. About him, both within the Party and among the masses whose thoughts it directs, language is used which goes beyond the flattery due to a successful political leader. A tribute in verse sent to Stalin a few years ago in the name of two million Russian workers hails him:

> O wise master! Genius supreme!
> Sun of the workers! Sun of the peasants! Sun of the world!
> Power of rivers, glory and pride of labour!

In a like vein the Ukrainian poet, Vetchora, sings:

> The greatness of Stalin is a halo
> Around the constellations of the firmament,
> Around men and factories.

These the are unmistakable accents of religious emotion, and they cause embarrassment to many English admirers of the Soviet system. The rationalist Webbs in their classic work

on it attribute the cult of Stalin to the backwardness of the Russian masses and express the pious hope that it will disappear with the spread of education It is not clear however why it should so disappear seeing that the schools themselves are among the principal agencies for promoting it I mention it here neither in approval or disapproval but simply to call attention to it as a fact in the contemporary world with which we have to reckon And after all why should it be a cause for astonishment? Western rationalism and individualism did not come to us from Moscow still less from Tiflis or Samarkand The Russian peasant never learnt to read French or studied the works of John Stuart Mill he did not in the eighteenth and nineteenth centuries cease to inhabit the world which Byzantine monks had made for him a world in which there should always be a Holy Orthodox Tsar who is ordained of God and cherishes his people It may be disappointing for those who wish to see in Russia the fulfilment of their own aspirations that the Russian masses should be so eager to worship and obey but Stalin has gained supreme power in Russia mainly because he has understood it so well In the contest with the "Westerners" whether of the older liberal and socialist parties or within the Communist Party itself, victory has gone to a man who is the son of a Georgian peasant cobbler born on the Asiatic side of the Caucasus who was trained for the priesthood, who speaks no languages but Georgian and Russian, and who has never been outside Russia except for two brief transit journeys

I have dwelt on the case of Russia because it is becoming evident with the passage of time that the Russian Revolution marked a turning point in the history of Asia, and this quite apart from the actual spread of Communism In two ways the example of Russia had a profound psychological effect everywhere in Asia and changed the direction of the tendencies which had previously been making for change In the first place there was now an alternative to the standard outline pattern of Western civilisation—an alternative which was not an archaic survival but a new, dynamic force operating on a grand scale I remember in Tokyo in the year 1929 seeing displayed in a bookshop a work on American democracy entitled "The Western Way" It was then still possible to commend

the principles of liberalism to Asia with the argument : these are the principles on which modern Western civilisation is based and without which no nation can flourish in this age. But in the eyes of young Asiatics there was now clearly another way very different from the first and competing with it ever more strongly with each year that passed. Whether Russia was regarded as primarily European or Asiatic by its historic tradition was immaterial ; in either case its creed was a challenge to the ideology of the Western nations which had most power and influence in Asia outside the borders of the Soviet Union.

Secondly, there was one aspect of the Soviet system which made a strong appeal in all Asiatic countries, not only to those who were sympathetic to Communism, but also to many who were bitterly hostile to it as a social doctrine. This was the technique of State control and planning of a closed national economy which had been evolved by the Soviet regime and was found to be detachable from the other main element of the Soviet economic order, the socialisation of all property in the means of production. That State control and planning of industry could be combined with the maintenance of capitalist property and could even be used to consolidate a capitalist counter-revolution was a discovery of fascism in Europe ; it was also discovered in Asia, partly under the direct influence of European fascism, but partly also in response to the specific needs of Asiatic nationalist movements. Asia as a whole was economically backward, lagging far behind Europe and America in industrialisation, and in all Asiatic countries nationalists were obsessed with the idea of "catching up" as quickly as possible in order to gain national independence or power. For such aims the processes of development by private capitalism seemed too slow, and also dangerous in view of the large part played by foreign capital in most of these countries. To achieve a rapid economic development while avoiding a perilous dependence on foreign capital it seemed better to rely on State planning, subsidy and direct investment in nationally important industries. Such an idea had all the more powerful an attraction because Asia, generally speaking, had never reached the stage of laissez-faire capitalist economy. In so far as industrial and commercial enterprise was European, it did not really belong to Asia, and

in so far as it was Asiatic, it was still very much crabbed and confined by a pre-capitalist social order, except to a certain extent in Japan—and even there business was marked by what would have been regarded in Britain or America as an excessive dependence on politics and governmental connections.

It is in relation to the new ferment of ideas produced in Asia by the Russian Revolution that we may now survey the main lines of historical development since 1920 in the four principal Asiatic countries outside the Soviet Union namely Japan, China, India and Turkey. The recent history of all these countries has centred round nationalist movements; this nationalism is of the secular, folk-based type characteristic of modern Europe, as contrasted with old dynastic, feudal and religious loyalties, though it tends to combine with these older loyalties where they are not too discordant with itself. In all four countries nationalism, starting with a liberal democratic ideology, has developed authoritarian tendencies, though only in one of them—Japan—has it so far assumed a form which can be classified by the title of fascism. In every case, though less in Turkey than in the more easterly countries, nationalism, beginning among the Western-educated intelligentsia and standing for Western-patterned reforms, has nevertheless come more and more to emphasise what is distinctive in the national inheritance and to ally itself with traditional sentiments.

The two primary aims of nationalism are national independence and national unity. In both respects India is in a condition different from the other three, for she is still subject to the sovereignty or paramountcy of a European power and she so lacks national unity that it is a matter for doubt whether she is one nation or two. At the other end of the scale Japan, always a geographically definite and ethnically homogeneous country, overcame her feudal particularism within two decades after Commodore Perry's alarming visit in 1853 and succeeded in preserving complete political independence—except for foreign extra-territoriality of which she had rid herself by 1901. Turkey, after a century of misfortunes and humiliations whose effects were symbolised by the imposing building in Constantinople significantly called the "Ottoman Debt," gained both national unity and genuine independence through a war in

which she lost nearly all of her empire over non-Turkish peoples, but defeated the victors of a great European war and compelled them to cancel the peace treaty which they had tried to impose upon her. China, after suffering a serious loss of sovereign rights and internal disintegration over a long period, had hardly regained her status as a united and independent State when she was threatened with complete subjugation by her neighbour Japan. Thus each country has had in recent times its separate lot of trial and tribulation ; the nation which had the least unhappy experience was Japan, yet it was among the Japanese, who had long been the most isolated, self-centred and inordinately proud of Asiatic peoples, that this epoch produced the most acute resentments.

Japan was the first Asiatic nation to westernise herself successfully on her own initiative in technology and State administration. Turkey had begun earlier, but as a result of prolonged vacillations between progress and reaction had not equalled the achievement of Japan by the end of the nineteenth century. Politically, Japan reorganised herself on the basis of a compromise between the old dynastic monarchy linked with Shinto as a State religion on the one hand and a parliamentary system on the other. The Constitution which gave form to this compromise, promulgated in 1889, was modelled on that of Imperial Germany, where a similar compromise between autocratic monarchy and parliamentarianism had taken place. It is not true to say that the Japanese Diet has never counted for anything ; it had a plurality of parties through which important organised interests carried on an active political life. But the Cabinet was not responsible to it, and by a peculiar administrative convention the armed forces were not really responsible either to the Diet or to the Cabinet. There was, however, nothing in the Constitution to prevent the Diet from gaining control in practice over both the Cabinet and the armed forces, and this was in fact the political trend of the years following 1918, when the victory of the Western democracies in their first war against German militarism gave liberalism in Japan an overwhelming prestige. This trend was reversed by the development of acute economic crisis and social unrest in Japan (especially as a result of the world depression in 1930), by the rapid growth of

Communism alarming to the propertied classes, by the example of Fascism in Europe and by the spread in the officers' corps of the Army of a doctrine akin to fascism, at once anti-Communist and anti-liberal, urging unqualified national egoism, expansion abroad and State economic planning at home. In 1931 the section of the Army stationed in the Kwantung territory on the mainland of Asia began aggressive military operations in Manchuria and finally set up the puppet State of Manchukuo, which became the base, not only for further wars and threats of wars abroad, but also for a political conquest of Japan itself for it is the so-called " Manchukuo men " who now rule in Tokyo.

Japan is the most highly-industrialised and technically efficient of the larger Asiatic countries outside the Soviet Union, and yet in its pivotal national idea it is the most primitive and archaic. Japanese military fascism has revived Shinto myth and the cult of the Emperor as the lineal descendent of the Sun Goddess, who is held to keep Japan under her special protection. The legends of the *Kojiki*, full of savage animist speculation and fancy without consistency or limit of theogony, were twenty years ago treated with a discreet scepticism by educated Japanese, and foreigners were not required to take them very seriously. A university professor even wrote a text-book which for thirty years was officially approved for law students, stating that the Emperor was " an organ of the State." But Japanese military fascism had this book suppressed, its author disgraced and the divine lineage and sovereignty of the Emperor placed beyond any hint of doubt. In the purified constitutional theory democracy was radically repudiated ; the Emperor's commission from the Sun Goddess to govern Japan gave him absolute sovereignty over his subjects and, if they were to be allowed any power in the State, it was by his free grant. The Japanese Emperor, according to Professor Fujisawa, a leading theorist of the new nationalism, is a " visible god " ; he is declared to be " infinite deity and finite mortality combined " ; he is unique in the world, the ruler of a chosen people. Nor does the Army have to stop at proclaiming Japan's own religion within her original borders ; the time has come to spread it through the world in order to unify mankind. In 1939 a shrine of the Sun Goddess was established in the palace of the

Manchukuo Emperor in Hsinking and another in the most southerly of the Mandated Islands in the Pacific looking towards New Guinea To-day one has been built in Singapore, the statue of Sir Stamford Raffles having been ceremonially consigned to the museum

All this has not at all increased the actual power of the Japanese Emperor indeed the turbulent progress of military fascism has caused nowhere greater alarm than among the officials of the Imperial Court who preferred a dignified security to the perilous elevation thrust upon them by soldiers who do not hesitate to shoot down the Emperor's own Ministers with machine guns Actually in the Army's scheme of things, the Emperor is more restricted than a constitutional monarch of a democracy he is expected to reign but not to govern What has happened in Japan is not really a restoration of an absolute monarchy which in fact has never been absolute since the ninth century but a military dictatorship using the Imperial name while drawing its motive power from a social and political movement very similar to German National Socialism The most remarkable feature of the new Japanese nationalism is the combination in it of an extremely archaic traditionalism with a revolutionary spirit expressing itself in slogans of a 'new structure and a new order Contemporary Japan cannot be explained merely in terms of political reaction and reversion to the past there is too much dynamic energy and will to innovation On the other hand it is highly significant that Japan has found in her own cultural inheritance and not in the store of her Western schooling the prime inspiration for a national activity which however perverted and incompatible with the real progress of humanity cannot fail to have far-reaching effects in the history of our times Though the fanatics of 'Nipponism' have undoubtedly been influenced by European Fascist and Nazi example, and though the crisis which gave them power in Japan was not a local, but a world-wide episode, they can rightly claim that they did not have to go to the West for the doctrine of a predestined *Herrenvolk* under authoritarian leadership

The recent development of Chinese nationalism has been in many ways very different, yet there has been a certain parallelism

In China the old monarchical regime has been swept away and democratic republicanism has been accepted as the political ideal, Anglo-American liberalism has had a more profound influence than it has ever had in Japan, and the conception of a peaceful order of international co-operation has gained a strong hold on educated opinion The outward aspect of Chinese life is being continually transformed and intensive industrialisation is being planned for the post war period Yet, in ideology and attitude of mind, there have been signs of a reaction against the westernising iconoclasm of the last generation, a reassertion of Chinese national individuality and an increasing disregard for Western opinion or advice The Chinese Revolution was mainly the work of the "returned student" the young man educated abroad, with a mind sharply wrenched away from the Chinese past and possessed by a new and alien civilisation But in recent years there has emerged more and more in China a type of men who are "Western-educated" but have never been outside China and derive their habits of mind from a social environment still peculiarly Chinese Men of this kind are found particularly in the officers' corps of the new army and in the local councils of the ruling Kuomintang party, they are as yet little represented among the personalities best known to the outer world, but their power is great and increasing, and it does not make for democracy as we understand it A certain note of bewilderment may be discerned in the comment of many foreign observers in China during the last few years their sympathy and admiration for China as a nation which has come of age as a modern State in a magnificent struggle against armed aggression are qualified by a sense of an enduring xenophobia, of something "difficult" and recalcitrant towards the Western world It is well that we should not expect China in the post-war period to be as amenable to Anglo-American world leadership as too many of our publicists lightly assume or even to be as dependent on foreign economic assistance as we would like to believe Victory in a great war will have restored to China her ancient pride and spiritual self-reliance, she will still have to send her engineers abroad for training and study, but politically and culturally she is likely to follow a path of

her own with a surprising, and sometimes perhaps disconcerting, originality.

In India the "westernisation" of a small minority through higher education, imparted in Britain or under British administration in India, began much earlier than in China. It produced men who had a knowledge of the English language and literature, of English constitutional law and political theory, such as very few Englishmen could equal, and who were sharply torn away from the mental environment which the vast majority of their countrymen continued to inhabit. Macaulay in his famous controversy with the "orientalists" argued that this must be so; the educated Indian must be uprooted and denationalised in order that he might lead his people to civilised rationality and ultimately to democratic self-government. From the Indians trained in Macaulay's school, indeed, came the founders of the new Indian nationalism with its progressive liberal and secularist ideas. But, as the movement grew and was propagated among the masses, leadership passed from politicians formed on the Gladstonian model to a strange figure whom Macaulay could never have imagined. Gandhi had enough of Western education to be at home in the modern world and to talk the language of twentieth-century nationalism, but in his role of an ascetic saint he was able at the same time to embody a deeper nationalism, the revolt of the Hindu religious tradition against intrusive Western culture With his loin-cloth, his goat and his spinning-wheel, his "non-violent resistance" and his fasts, he drew a response from the heart of the Indian masses with which leaders of far greater practical ability were unable to compete. Most Englishmen who have had to deal with Gandhi have considered him "impossible" and many of his fellow-countrymen hold the same view, yet for two decades he has been the most influential figure in Indian politics and at the time of speaking the end of the drama of Gandhi's fight with the Government of India is not yet. Nor, if Gandhi were to disappear from the scene tomorrow and his special doctrines were to be discredited, would it alter the fact that the course of events in the last few years has brought India further away from, rather than nearer to, that orderly transition to democratic self-government to which men of goodwill both in Britain and

in India have long looked forward. The claims of the Congress Party to a kind of divine right, the open admiration for the undemocratic 'tutelage' rule of the Kuomintang in China, the insistence on Hindustani instead of English as the common language of India and the consequent raising of the question of the status of Urdu, the new sharpening of religious antagonisms and the rise of the Moslem League and the Mahasabha as rival political organisations, all these things are portents of a turbulent and troubled future in which forces which have been considered as moribund and negligible may play a surprising part under a new modernist guise. But whatever the outcome may be, it is likely to be something more essentially and peculiarly Indian than an observer of twenty years ago would have expected.

At the western extremity of Asia and on the shores of Europe's oldest seaway, where Hellenism, the creative power of Western civilisation, had its birth, is to-day the Republic of Turkey, the residuary legatee of the great Ottoman Empire and of the Caliphate of Islam. Westernising reforms began in Turkey more than 100 years ago, but it was only after the disaster of 1918 and the occupation of the Ottoman capital by the forces of the victorious enemy that the revolutionary nationalists led by Kemal Ataturk established a national secular republic with formal popular sovereignty and an enforced wearing of European clothes. Although there has been a reaction in certain respects since the death of the great reforming leader, there is reason to believe that the process of westernisation has been more decisive in Turkey than in Japan, China or India, because the traditional Islamic culture of Turkey was of alien, *i.e.*, Arab and Persian, origin, and was therefore the more easily ousted by a nationalist movement laying stress on Turkish national identity, whereas the traditional culture-systems of China and India—Confucianism and Hinduism—are indigenous with continuity of independent development from remote times, and even the meagre content of Japanese Shinto is derived from Japan's own ethnic origins. Detached from his borrowed Arab-Persian cultural tradition, the Turk has only his language and his history as a migrant, warrior and ruling race; writing his speech in a Latin alphabet, therefore, it is not hard for him to feel that he is closer to Europe than he is to his Asiatic neighbours.

To sum up our survey and also to return to our starting point the general trend of contemporary history in Asia seems to show neither a simple reception of Western civilisation nor yet a straight reaction of traditional Asiatic cultures against it but a modification of Western forms conditioned by the Asiatic past into new and sometimes very strange types I have tried as far as I can to avoid commendation or censure my aim has been to analyse and to understand The scale is too large for sweeping generalisations and I am well aware that some at least of the statements I have made in this paper are too simple for the complexity of the issues with which they deal But amid the endless detail of the world which confronts us and the confusing torrent of events in this time of the greatest of wars an attempt to depict the scene in firm outlines may be useful towards a better understanding One half of the total number of mankind dwells in Asia and what they think, feel and do cannot be a matter of indifference to us whether we are concerned with export trade or with the organisation of peace in the world or with spiritual and cultural values

Samuel Greg and Styal Mill.

By Frances Collier, M A

I

Twenty-five years ago a begging letter to Lieut Colonel Alexander Greg brought a generous response in the form of an invitation to visit the Quarry Bank Mill at Styal and inspect the business records the firm had preserved As a result of the visit a valuable set of documents was put at my disposal These included ledgers containing the accounts of the shop, farm, cottages and apprentice house connected with the mill, wages books a cash book, in which were entered the sums borrowed by operatives from their employers and their weekly repayments indentures of apprenticeship and other manuscripts— all of which enabled me to piece together a picture of the working life, earnings and social conditions of an early factory community

The Quarry Bank Mill dates from the dawn of the factory system in the cotton industry It was twelve years or so after Arkwright had obtained his patent for spinning cotton by rollers that Samuel Greg, one of the younger members of the large family of a Belfast shipowner, was invited by his mother's family (who lived in Ardwick) to come to England with a view to starting cotton spinning with their assistance He accepted the invitation and came to Manchester, where he soon realised the possibilities in the new industry, and determined to set up in business for himself After exploring Lancashire, Derbyshire and Cheshire in search of a favourable place for his venture, he finally selected a site below the junction of the Bollin and Dean water at Styal

In order to see this little factory community in the right setting it is important to remember that it was established at a time when revolutionary changes were taking place in industrial technique The technical history of the early cotton trade falls into three clearly-defined periods (i) before the introduction of machinery; (ii) when water-power was the main source of energy and Arkwright's water-frame the principal spinning machinery, (iii) when steam power and the mule became predominant. These three stages also form well-marked periods in the social history of the cotton workers; for the technical changes brought with them alterations in the type

of labour demanded in the different processes The effect on the lives of the workers and their families was profound

Before the introduction of power driven machinery the manufacture of yarn and cloth was carried on in the houses of the workers and provided employment for all members of the family capable of labour spinning and its preparatory processes were the work of women and children and weaving mainly the work of men These workers were not in any sense independent craftsmen they were the employees of manufacturers but the work was performed in their homes

The second period begins with Arkwright's success in establishing the factory industry which took spinning and many of the preparatory processes out of the home into the factory This change created a demand for labour at particular places whereas the people who had previously performed the work had been scattered far and wide in the cotton manufacturing area For people to have followed their work into the factory would have meant migration and as the early spinning mills required little skilled male labour there was no great incentive for the weavers and their families to make the change Hence many of the factory masters resorted to the apprenticeship system and those adult workers who moved to the neighbourhood of the factories were largely either unskilled or were men with families for whom employment in a cotton mill meant a substantial increase of income

It was at this time that men began to lose their monopoly of weaving When their families were no longer able to find employment in the preparation and spinning of cotton because these had been taken into the factory the weavers naturally sought work for them in weaving This hastened a development which was inevitable when it was found that neither a man's strength nor much skill was needed to weave the cloths manufactured from the factory spun yarn From the 90's onwards women, boys and girls were employed in increasing numbers weaving calicoes, coarse muslins and cambrics on hand looms under a putting-out system

The third phase starts with the application of steam power to the mule, and the consequent growth of the cotton industry in towns There is, of course, no rigid line of demarcation

between the two periods of factory development, but it is well known that after the introduction of steam power the industry tended to concentrate in towns. With the expansion of mule spinning, and the improvement of the machinery used in the preparatory processes, the demand for skilled male labour increased and the abnormal demand for child labour diminished.

Before making generalisations as to the circumstances of the workers it is necessary, therefore, to refer to the stage of development reached by the industry and also to take account of the great differences that existed between conditions in the towns and those in country districts. In places such as Manchester, Bolton and Stockport the workers lived their private lives free from interference, obtaining their houses, food and clothing, and educating their children, in whatever way they were able, or as seemed to them best. In the country, however, many of these needs had to be provided by the employer, and this gave him a power he could use for good or evil : his personal character determined, to a large extent, not only the working conditions, but also the whole lives of the little group of people dependent upon him for employment. Such a community was centred round Quarry Bank Mill.

The exact date at which Samuel Greg left Belfast and the length of time it took to build the mill are uncertain. But it is known that the factory began working in 1784, cost £16,000 to erect, and, according to his own statement, nearly ruined Mr. Greg. The bulk of the yarn produced was sold in Manchester for the home market, but some yarn was put out among the hand-loom weavers at Eyam in Derbyshire, where the cloth woven was a mixture of linen and cotton. Despite the fact that the machinery installed proved to be of inferior quality, the business prospered, and in 1796 Peter Ewart (who had erected one of the first engines to drive cotton machinery, at Drinkwater's factory in Manchester about 1789) was taken into partnership by Mr. Greg.* To this partnership Mr. Ewart "brought no capital but extensive mechanical knowledge." He seems to have been responsible for great alterations and extensions of the factory, and within a few years a new wing

* The partnership lasted five years, later Peter Ewart started in business for himself in Peter Street, Manchester, as a mule spinner.

was built, the roof was raised and a new storey constructed; a second water wheel made of iron (the first used in the country) was installed; and, in 1800, a 10-horse-power engine was put down and some water frames of an improved type were added to the existing plant. By 1815 there were 4,416 spindles at work.

Mr. Greg does not appear to have suffered severely from the post-war depression, for, in 1818, he began extensive improvements which included the making of a tunnel, and a wheelrace, an addition to the mill, and more new machinery. The cost of this extension, according to the records, was as follows:

Tunnel and wheelrace	£5,000
Water-wheel	£2,300
Mill extension	£2,700
Water frames, at 12/3 a spindle	£1,764
	£11,764

This was the last big change at Quarry Bank during times of prosperity. The place could not be expanded on a big scale and it was considered inadvisable to build another mill in a situation where it was so difficult to obtain labour. Hence subsequent developments were made in other districts; and between 1823 and 1833 Mr. Greg and his sons acquired mills at Bury, Lancaster, Caton (near Lancaster) and Bollington.

After the collapse of 1825-6 the Styal business suffered severely. Mr. Greg resisted the introduction of the power-loom weaving by means of which his fellow spinners were retrieving their losses. The balance sheets of the firm from 1825 to 1838 give ample proof of the losses on spinning certain counts and the necessity for combining spinning with weaving if a continuance of these were to be avoided. In 1834 Mr. Greg died, and the following year power-looms were installed. The cloth manufactured was still "union," a mixture of linen weft and cotton warp. Later, however, yarn for weft was bought in Manchester and cloth entirely of cotton was manufactured. In 1838 a new weaving shed was built, and mules were bought from Sharp and Roberts so that the yarn for weft could be spun in the mill. These changes

were beneficial, and from 1840 onwards the concern, though not immune from changes of fortune, was generally prosperous.

It is now time to turn to a consideration of the circumstances and social life of the workers at Styal. Having built his mill in a place with a very scanty population, Mr. Greg had to obtain the labour he required from other places, and also had to provide for the needs of the families he persuaded to settle at Styal. To do this he built cottages, or bought farms and made them into cottages, and opened a shop, which, judging from the bewildering variety of commodities stocked, was a forerunner of Harrods. As the colony increased in size, a farm was bought which supplied the workpeople with milk, butter and other farm produce. In 1822 a chapel was built—many of the operatives were Baptists—and a minister was engaged at a stipend of £80 per year. The following year an institution for lectures and social functions, and a school, were erected at Styal.

The labour imported into the mill was of three types: (*a*) apprentices taken from the workhouses (no children younger than nine years were ever employed at this mill) who were housed, clothed and fed, but who received no wages; (*b*) apprentices, who were engaged by a contract made direct with their parents, and who were housed and fed (but not clothed) and paid a small weekly wage ranging from 9d. to 1/6; (*c*) free labour, much of which was obtained through Cheshire overseers and taken from Buckingham and Berkshire through the Poor Law Commissioners.

Before discussing the facts which have been collected about this little community something must be said about the records used. The material preserved consists of a set of account books covering the period 1790—1857. The books which relate to the workers are wages books for the years 1790–91, 1831–32, 1847–48–49–50, 1854–55–56–57, and a book containing the "balance of wages paid" from January, 1822 to June, 1824, which is a record of the amounts deducted for rent, and shop and farm goods from the earnings of each family, and the cash paid to the heads of these families. It is clear that up to June, 1824, the operatives did not receive their wages to spend as they liked. But from 1831 the only deductions were for rent,

and payments towards debts, which were stopped out of the wages of one member of the family— a practice which suggests that the operatives were then directly discharging their own liabilities so far as the bulk of their purchases were concerned.

The shop accounts cover the period 1823–28, and give a statement of the goods purchased for the shop, the general running expenses, the sales, and profits. The farm book contains the amounts of milk and butter sold to the villagers every day from 1825 to 1831. The Apprentice House accounts relate to the years 1823–28 and give the cost of maintaining the apprentices.

The debt cash book covers the years 1828 to 1841, and gives many glimpses of the characters of the borrowers. There are shiftless people who borrowed to pay off bills which had been run up at the shop (the operatives not always being as prompt with their payments as the book-keeper had been with the deductions under the older system), and thrifty people who borrowed to buy pigs, which they later sold to the shop as bacon. Many persons borrowed money to buy clothing, and some for the funerals of relatives (the mill operatives had a funeral club). In short, money was borrowed for any transaction the negotiation of which was beyond the surplus of a weekly wage. The amounts lent varied from £1 to £20, the latter sum appearing, however, only on very rare occasions. Indeed, the majority of loans were of small sums which were paid off at a rate of from 1/- to 5/- a week.

II.

From the wage books tables have been compiled showing the numbers, occupations and earnings of the workers in 1790, 1831 and 1848.

In February, 1790, there were 183 free labourers and 80 apprentices employed at the factory. These 183 wage-earners were distributed as follows :

Spinning rooms ...	56	Labourers	8
Carding rooms... ...	77	Smiths...	3
Reelers	22	Joiners	2
Packers	4	Clockmakers ...	7
Roller coverers ...	2	Turners	2

The wages they earned were :

Carding rooms.

	s. d.		s. d.
Overlooker	15 0		—
Head Carders	9 0	to	11 9
Carders	4 0	to	5 0
Creel Tenters	1 6	to	3 0

Spinning rooms.

	s. d.		s. d.
Overlookers	12 6	to	13 0
Spinners	4 0	to	5 6
Learners	2 6	to	3 0
Doffers	1 6		—
Reelers	4 6	to	4 9

Miscellaneous.

	s. d.		s. d.
Packers	9 0	to	10 0
Clockmakers	14 0	to	25 0
Turners	15 0	to	19 0
Joiners	12 0	to	17 0
Smiths	13 0	to	14 0
Labourers	9 0	to	10 0

These wages are time-rates for a 12-hour day : as trade was good in 1790 longer hours were worked and overtime was paid. Even the apprentices were paid something when they worked more than 12 hours a day, for each week there are long lists of payments to apprentices of sums ranging from 3d. to 1/-.

By 1831 the wage-earning workers had increased to 351 and the apprentices to 100. Wage rates were higher and there was a considerable increase in the number of adult and better-paid workers.

The Gregs had been badly hit in the panic of 1825–26 and the depression that followed, so it is almost certain that the improvement in wages was fairly recent. There are no wage-books for the 20's, but the decline in purchases of clothing, milk and butter in the later years of the decade suggests that the workers shared in the reduction of wages which was general throughout the cotton industry.

Of the 351 people employed in 1831, 115 were in the Carding Room, 87 in the Spinning Room: the remainder consisted of pickers, scutchers, reelers, winders, mechanics, warehousemen and labourers.

WAGES.

	s.	d.		s.	d.
Scutchers	9	0	to	15	0
Boys	2	6			—
Winders:					
Overlookers	11	0			—
Winders	2	0	to	4	0
Reelers:					
Overlookers	16	0			—
Reelers	5	0	to	10	0
Carding rooms:					
Head Carder	17	0	to	18	0
Carders and Framers	4	6	to	10	0
Creel Tenters	2	3	to	3	6
Spinning rooms:					
Overlookers	17	0	to	18	0
Spinners	6	6			—
Learners	3	6			—
Dofters	2	0	to	3	0
Warehouse:					
Adults	9	0	to	15	0
Youths	2	0	to	5	0
Mechanics:					
Adults	18	0	to	22	0
Youths	9	0			—
Odd hands	8	0	to	13	0

By February, 1848, power-loom weaving had been introduced and the apprenticeship system had been abandoned. The

personnel of the mill was now 421 wage-earners, and the improvement of the economic position of the workers due to the introduction of power-loom weaving is shown in the following table :

Wages.	Numbers employed. 1790	1831	1848
Under 2/-	13	6	32
2/- and under 3/- ...	30	67	18
3/- ,, 4/- ...	18	41	50
4/- ,, 5/- ...	41	24	16
5/- ,, 6/- ...	38	35	30
6/- ,, 7/- ...	1	78	77
7/- ,, 8/- ...	2	10	57
8/- ,, 9/- ...	2	9	49
9/- ,, 10/- ...	9	13	18
10/- ,, 12/- ...	8	24	11
12/- ,, 15/- ...	10	17	28
15/- ,, 20/- ...	7	19	25
20/- ,, 25/- ...	1	5	10

The source from which the Gregs drew their labour has already been indicated ; the low wages they offered would not attract town labour, and therefore they communicated with parish overseers, who put them into touch with needy and suitable families. To those eking out a miserable existence with the assistance of poor relief, work in this mill meant a good house and decent food and clothing, instead of a wretched hovel, starvation and rags.*

* Dr Kay, in his report on the migration of labourers, in the First Report of the Poor Law Commissioners, 1835, gives the contracts of three families Greg & Sons engaged through the Poor Law Commissioners :—

John Howett's Agreement : 24/- first year, 27/- second year.

			s	d
John Howett, employed as foreman, aged	38	... ...	12	0
Mary Ann, factory ... ... ,,	16	... ...	4	0
Ann, ,, ... ,,	14	... ...	3	6
Celia, ,, ... ,,	12	... ...	2	0
Timothy ,, ... ,,	10	... ...	1	0
No younger children.			24	0

[For continuation, see footnote overleaf.

However, the miserable circumstances from which the Gregs took some of their employees do not account for people staying in Styal once they had got their bearings in the new work and had heard of the wages offered in other districts. Probably many did move on to seek their fortunes in fields that offered greater opportunities, but, as has already been mentioned, the wage books show that some families remained in the employ of the firm generation after generation. To understand this contentment with low wages we have to remember that Styal was situated in an agricultural district where wages were low and there was little employment for women and children, and that life in Styal offered many advantages—pleasant surroundings, a good cottage and large garden, steady work, and the social ties formed by living in a small self-contained community—all of which must have weighed heavily in the balance when a move was being considered. In view of these conditions it is not difficult to account for the entire absence of trade unionism among the factory hands; very probably the more spirited members of the community migrated to other places, and those who remained in Styal acquired the placid outlook on life of their agricultural neighbours.

John Stevens' Agreement. 26/- first year, 29/- second year.

			s.	d.
John Stevens, labourer,	aged	38	12	0
Elizabeth, factory	,,	18	6	0
Rebeckah, ,,	,,	14	3	6
James, ,,	,,	12	3	0
Mary, ,,	,,	10	1	6
Five younger children.			26	0

Hannah Veasey's Agreement: 20/- first year, 23/- second year.

Hannah Veasey, widow.				
Samuel, factory	aged	18	7	0
Fannie, ,,	,,	16	6	0
Henry, ,,	,,	14	3	6
Joseph ,,	,,	12	2	1
Mary, ,,	,,	10	1	5
			20	0

These families came from Hedlow (Bucks) where the men earned 6/- or 7/- a week and 30/- to 40/- at harvest time, the women from 1/- to 3/- and girls from 6d. to 1/6 a week in lace making. They lived under the most miserable conditions conceivable, cottages with mud floors, fires only lit for cooking, without furniture, and with little food.

III.

There is in this material little evidence as to the cost of living at Styal, but plenty of evidence as to the kind of food eaten by the workers' families. Flour, meal, potatoes, bacon, a little fresh meat, cheese and large quantities of skimmed milk were the staple foodstuffs sold to the operatives and their families. The better-off families always had new milk and butter, and nearly all families had at least half a pound of butter a week in days of prosperity; but in the hard times of the late 20's butter became a luxury beyond the means of all but men earning the highest wages; even the consumption of skimmed milk, at 1d. a quart, had to be cut down.

The only articles for which prices are given are new, skimmed, and sour milk, cream and butter, which, as one would expect in an agricultural district, were sold at prices considerably below town prices. This would probably be the same in the case of all farm produce, such as bacon, cheese and vegetables. The prices paid for the other commodities would, of course, depend on the way in which the Gregs took advantage of their monopoly of sale.

The shop accounts afford us a glimpse of human nature which shows how quickly an increase of income is reflected in the attire of the women and girls. There are no wage books for the '20s, but it is probable that wages were increased through overtime. Before 1825 the shop stocked pattens, or clogs, and shawls for its women customers, but during 1825 hats and shoes figure in the accounts; £21. 7s. 3d. was laid out on millinery, and "plate" hats were evidently the fashionable shapes in Styal. The boom in hats did not last long, for declining trade checked the spread of the new fashions; only about £10 was expended on hats in 1826, and still less in the next two years, and clogs once more became the principal footwear.

To be just to the women it must be added that they took advantage of the period of prosperity to replenish their household goods generally, and a brisk trade was done in blankets, calico, cambric, stockings, underclothing and clothing of all kinds. The shop laid out £318. 16s. 9d. on these goods in 1824, £490 13s. 7d. in 1825, but only £314. 3s. 6d. in 1827. Judging from the shop sales it would appear that no serious privations

were suffered up to the middle of 1828. In 1829, however, the position became more serious, as has already been indicated in the account of the sale of dairy produce.

IV.

Five minutes walk from the Quarry Bank Mill, along a pretty lane, is the Apprentice House, where for 63 years the indentured children employed by the firm lived. The story of the way in which some manufacturers took advantage of their power over the apprentices in their care makes one of the darkest chapters in the early history of the factory industry. The Greg family, however, took special pride in their treatment of these children. They claimed that their apprentices became healthy, respectable and industrious young people, considerably above the average of the neighbouring population. Of the boys who were receiving a few pence for working overtime in 1790, several rose to the best positions in the factory, and became overlookers, mechanics and so on. In the 1831 table, in the section dealing with family incomes, names such as Pepper, Heath, and Venables are known to be those of the families of men who were apprenticed in 1790. One of the apprentices became book-keeper to the firm, and at least two of the managers at the mill started their industrial careers as parish apprentices. These are only a few instances casually met with, and in view of the facts that the firm always kept from 90 to 100 apprentices until they were abandoning the system, and that many hundreds of children must have passed through their hands, it is impossible without a careful investigation to say whether their apprentices usually had a prosperous career. It may be said, however, that, unless the apprentices of 1790 were a very superior set of boys, there are grounds for the claims made by the firm.

Indentures which are in existence show that the children were brought from all parts of the country : Newcastle-under-Lyme, Liverpool, London, and many Cheshire parishes are mentioned as their birthplaces. A description of their life as apprentices is preserved in a newspaper report of the prosecution of two boys before a Middlesex magistrate, on a charge of "having eloped and deserted the service of Samuel Greg." The magistrate questioned them closely about their life at

Styal, and was informed by them that there were 42 boys and a larger number of girls lodged at the Apprentice House. The children were under the care of a master and mistress, the boys being accommodated on one side of the house and the girls on the other. Two apprentices shared each bed and the beds were clean and comfortable, for the sheets were changed once a month! The Apprentice House was also kept very clean, the rooms were aired every day, washed frequently and whitewashed once a year. The children were given new Sunday clothes every two years, and new working clothes whenever they needed them. For breakfast and supper their food consisted of oatmeal porridge and milk, bread and milk, or milk porridge, for dinner they had boiled pork, bacon, potatoes, peas, beans and other vegetables when in season; and on Sundays there was beef, mutton or veal. Milk was the usual drink, but the apprentices were given tea when ill. Sunday mornings were spent at church, and Sunday afternoons at school; in the evenings the children were free to play. The boys also had to attend school one night a week, eight boys going each night. The runaway apprentices concluded their evidence by saying they had no complaints to make against their employer: they had left him, they said, because they wanted to see their mothers.

Evidently these were by no means the only apprentices who ran away from Quarry Bank, for many of the indentures preserved there bear a record of the conduct of the persons to whom they refer—when they ran away, where they were found, whether they were taken before magistrates, and so on. The dash for liberty was made several times by some hardy spirits, and this is not surprising, for life spent between an apprentice house and a factory, far from relatives, must have been monotonous in the extreme, even if the conditions were exceptionally good in comparison with those usually provided for children taken from overseers.

The statement of the boys about the amount of education given describes the schooling provided for apprentices as long as the system lasted. Part of the teaching was given by members of the Greg family. The daughters spent their Sunday afternoons teaching the girls, and the sons taught the boys. All the children

were taught reading, writing and arithmetic; the girls were also taught to sew and were trained in housework. In the accounts for the 20's two men are mentioned as being paid small salaries for teaching at the school, and two "singing masters" were also employed.

These parish children undoubtedly constituted cheap labour, but the accounts of the Apprentice House rather suggest the conclusion that where the employer discharged his responsibilities adequately, the labour which he housed, clothed and fed was not as cheap as free labour. Possibly these are the reasons for the rapid disappearance of the apprentice system from the cotton industry once free labour could be obtained.

The firm made a calculation of the cost per head of the apprentices at eight different periods, and the results are interesting if only for the light they throw on the rise of the cost of living in the 40's. In 1790 the cost per week was 3/6; in 1822, 5/0¼; in 1830, 5/0½; in 1835, 4/2; in 1840, 4/5; in 1842, 6/5½; in 1846, 9/2; and in 1847, 13/4.

The last apprentices finished their term of service in 1847, and the Apprentice House was then turned into a private dwelling.

EXAMPLES OF WAGES EARNED

1790

Family	*No of workers*	*Sex and probable age*	*Occupation*	*Av ge w'kly income during 8 weeks Jan 23–Mar 20* £ s d
Brierley	...Eight	2 men, 2 women 4 children	Packer, labourer, women and children carding	2 0 6
Armitt ...	...Five	...Man youth, girl two children	Smith, winder, youth girl and child carding	1 8 1
Swan ...	...Four	..Man 3 children	Head carder, children in carding room	0 18 2
Massey ...	...Four	...Man 2 women, girl	Roller coverer, spinners girl in spinning room	1 4 3
Richardson	...Four	...Woman youth 2 children	All in carding room	0 12 6½
Leigh ...	...Four	...Woman girl boy child	Reeler, others in carding room	0 15 8½
Craven ...	...Four	...Man youth 2 women	Labourer, spinners...	1 0 11½
Swayne	...Three	...Man 2 children	Frame cleaner dotters	0 10 4½
Gallimore	...Three	...Woman girl, child	Reeler, winders ...	0 12 8½
Hayman	...Three	...2 women, girl	Spinners...	0 13 7½

1831

Family	*No of workers*	*Sex and probable age*	*Occupation*	*8 weeks May June 25* £ s d
Bailey	...Nine	...Man, 2 youths 4 women 2 children	Odd hand, 2 saddlers, 2 spinners carder reeler, 2 winders ...	2 16 4
Johnson	...Seven	...Man, 3 women, youth, 2 children	Maker up, winder, others in carding room	1 18 10
Venables	...Six	...Man, 2 youths, 2 women, boy	Mechanic, maker up, picker, 2 spinners, winder, carding room	1 15 11
Gleave ...	...Five	...Man, woman, 3 children	Overlooker of carding room picker, children in carding room ..	1 10 11½
Leigh ...	...Five	...Woman, youth, 2 girls, child	Picker, others in carding room... ...	0 18 0
Pepper ...	...Four	...2 men, 2 women	Mechanic, carder spinner, reeler... ...	1 19 1
Coppack	...Four	...2 women, 2 youths	Odd hand, reeler carding room . ..	1 2 6
Tongue...	...Three	...Man, 2 women	Overlooker, reeling room, reeler, picker	1 9 6
Heath ...	...Three	...Man, 2 children.	Overlooker of spinning room, dotters ..	1 13 4½
Goodier...	...Three	...Woman, 2 youths	Spinner, carding room	0 17 9

Family.	*No of workers*	*Sex and probable age*	*Occupation*	*Av'ge w'kly income during 8 weeks* Feb –March 1848 £ s d
Bower ...	...Seven	...Man, 4 women, 2 youths	5 weavers, youths on mules	2 16 1½
Ollier ...	...Five	...Man, 2 women, 2 children	Odd hand, 2 spinners winder, child in card room	1 10 0
Steevens	...Five	...2 women 2 youths, girl	2 weavers, reeler, winder mule spinner	1 5 7½
Witney...	...Five	...Man youth, 3 women	2 spinners 3 weavers	2 0 0½
Spromson	...Five	...2 men, 3 women	Weavers...	2 13 9½
Hatch ...	...Four	..2 women, girl child	2 weavers winder girl in warehouse .	0 19 10½
Revitt ...	...Four	...Man, youth, woman, child	Odd hand, scutcher winder carder ..	1 3 0½
Morrall...	...Four	...2 men, 2 women	Mechanic warehouseman 2 weavers	2 8 4
Worthington	Four	...Man, woman girl child	Scutcher spinner, cardhand winder...	1 2 6

CONTRACT WITH PARENT FOR SERVICES OF TWO CHILDREN.

BE IT REMEMBERED, It is this Day agreed by and between *Saml Greg* of *Manchester*, in the County of *Lancaster, Cotton Manufacturer* of the one Part, and *Thomas Smith, Hatters,* of *Heaton Norris in the County of Lancaster* of the other Part, as follows, That the said *Thos Smith Agreeath that Esther and Ann Smith* shall serve the said *Saml Greg* in his Cotton-Mills, in *Styall* as a just and honest Servant, *Thirteen* Hours in each of the six working Days, and to be at *theair* own Liberty at all other Times; the Commencement of the Hours to be fixed from Time to Time by the said *Saml Greg* for the Term of *Three* Years at the Wages of *one Penney per Week and Sufficient Meat Drink and Apparell Lodging washing and all other Things necessary and fit for a Servant.*

And that if the said *Esr and Ann Smith* shall absent *themselves* from the Service of the said *Saml Greg* in the said working Hours, during the said Term, that the said *Saml Greg* may not only abate the Wages proportionably, but also for the Damages sustained by such Absence. And that the said *Saml Greg* shall be at Liberty, during the Term, to discharge the Servant from his Service, for Misbehaviour, or want of Employ.

As Witness their Hands, this *Twenty Eight* Day of *Jany* 1788——

By me Thomas Smith

Witness

Mattw Fawkner

CONTRACT WITH ADULT WORKER.

BE IT REMEMBERED, IT is this Day agreed by and between SAMUEL GREG, of Styal, in the County of Chester, of the one Part, and *Wm Chadwick* of *Styall* of the other Part, as follows: That the said *Wm Chadwick* shall serve the said Samuel Greg in his Cotton-Mills, in Styal, in the County of Chester, as a just and honest Servant, *Twelve* Hours in each of the six working Days, and to be at *his* own Liberty at all other Times; the Commencement of the Hours to be fixed from Time to Time by the said Samuel Greg, for the Term of *one* Year at the Wages of *foureteen Shillings per Week.*

And that if the said *Wm Chadwick* shall absent *him self* from the Service of the said Samuel Greg, in the said working Hours, during the said Term, without his Consent first obtained, that the said Samuel Greg may abate the Wages in a double Proportion for such Absence; and the said Samuel Greg shall be at Liberty, during the Term, to discharge the Servant from his Service, for Misbehaviour, or Want of Employ.

As witness their Hands, this *fiveth* Day of *Feby* 1791.

William Chadwick.

Witness
Mattw Fawkner

T Payne Churchwarden

two PENCE & pair

A

Thos Barratt Overseer

Sam.l Grey

John Bailey his X Mark

THIS Indenture, made the Twentyfourth Day of June in the Twenty Sixth Year of the Reign of our Sovereign Lord Geo: the third by the Grace of God, of Great-Britain, France, and Ireland, King, Defender of the Faith, and so forth; and in the Year of our Lord One thousand seven Hundred and Eighty Six Witnesseth That Thomas Payne Church-Warden of the Parish of Borough of Newcastle under Lyme in the County of Stafford And Thomas Barratt Overseer of the Poor of the said Borough Parish, by and with the consent of his Majesty's Justices of the Peace for the said Borough whose Names are hereunto subscribed, have put and placed, and by these Presents do put and place John Bailey aged fifteen Years a poor Child of the said Parish, Apprentice to Samuel Greg of Manchester in the County of Lancaster Esq.r Cotton Manufacturer with him to dwell and serve from the Day of the Date of these Presents, until the said Apprentice shall accomplish his full Age of Twenty one years according to the Statute in that Case made and provided. During all which Term the said Apprentice his said Master faithfully shall serve in all lawful Business, according to his Power, Wit, and Ability; and honestly, orderly, and obediently, in all things demean and behave himself towards his said Master and all his during the said Term. And the said Samuel Greg for himself, his Executors and Administrators, doth Covenant and Grant, to and with the said Church-Warden and Overseer and ~~every~~ each of them, their and ~~every~~ each of their Executors and Administrators, and their and each ~~every~~ of their Successors, for the Time being, by these Presents, That the said Saml Greg the Master the said Apprentice in the art business of Cotton Manufacturing which he the said Saml Greg now useth shall and will teach instruct or cause to be taught and instructed in the best way and manner that he can for of the Term of the Service of the said apprentice And shall and will during all the Term aforesaid find, provide, and allow, unto the said Apprentice, meet, competent, and sufficient Meat, Drink, and Apparel, Lodging, Washing, and all other Things, necessary and fit for an Apprentice. And also shall and will so provide for the said Apprentice, that he be not any way a Charge to the said Parish, or Parishioners of the same; but of and from all Charge shall and will save the said Parish and Borough and Parishioners harmless and indemnified during the said Term. In witness whereof, the Parties abovesaid to these present Indentures, interchangeably have put their Hands and Seals, the Day and Year above-written.

John Boles of the parris of Trentam

Sealed and deliver'd in the Presence of / the Interlineations being first made and observed by

Matt.w Fawkner

WE whose Names are subscribed, Justices of the Peace for the Borough aforesaid, (one of us of the Quorum) do consent to the putting forth of the abovesaid John Bailey Apprentice, according to the intent and Meaning of the above Indenture.

Jn.o Tilstone Mayor

J Berkett

PROCEEDINGS OF THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

Obituaries.

CHRISTIAN FREDERICK BUDENBERG.

Born May 2nd 1864. *Died November 12th* 1941.

Christian Frederick Budenberg was born in Manchester on May 2nd 1864. He graduated at Owens College in honours in engineering in 1883 and was awarded the engineering essay prize. After serving his apprenticeship with Messrs. Gresham and Craven of Salford he was articled to Mr. Lloyd Wise, patent agent. In 1886 he joined the staff of the journal *Industries* as sub-editor, and in 1887, at the age of twenty-three, became secretary of the engineering section of the British Association.

During 1888 he was employed at Messrs. Schaeffer and Budenberg's works at Magdeburg, Germany, and in January 1889 he returned to Manchester as the firm's manager in England, later becoming managing director.

On the formation of the successor firm, Budenberg Gauge Co. Ltd., he became chairman and managing director.

At his death on November 12th, 1941, he had thus for more than 50 years been associated with the design and production of pressure gauges and other non-electrical instruments. He was responsible for many advances in the design and manufacturing methods of the instruments in which he had specialised.

C. BUDENBERG.

R. B. WILD, M.Sc., M.D., F.R.C.P.

Born, 1862. *Died*, 1942.

Born at Holcombe, Bury, 1862, R. B. Wild became a student of Owens College, and in 1883 graduated B.Sc. (honours in physiology), at the Victoria University. In the Inter. M.B. he won the gold medal in physiology.

Qualified L.S.A. in 1884, he obtained the London M.B. in 1886 and in 1887 he was awarded the M.D. with gold medal.

He began practice in 1886 and was for many years Registrar in Pathology at the Manchester Royal Infirmary. Later he joined D. J. Leech in the department of materia medica and therapeutics of Owens College, and when Leech retired he succeeded to the Chair, which was made a whole-time one.

He was elected F.R.C.P. in 1912.

In the University he was for many years Dean of the Medical School and for a time acted as Pro-Vice-Chancellor. He also represented the University on the General Medical Council.

In his consulting practice he specialised in diseases of the skin and was for many years an Honorary Consulting Physician to the Manchester and Salford Hospital for Diseases of the Skin. He played an active part in the foundation of the Christie Cancer Hospital and later in its administration. He was also physician to the hospital. In addition he served as a Major in the R.A.M.C. A prize in pharmacology—known as the Wild Prize—given annually by the University of Manchester, was endowed by him.

ARTHUR HENRY WORTHINGTON.

Born, February 2nd, 1860. *Died, September 4th*, 1941.

A. H. Worthington, a member of an old and distinguished Manchester family, was a son of Samuel Barton Worthington, one time chief engineer of the old Lancashire and Yorkshire Railway Company. He received his early education at Castle Howell School, a famous school founded in Lancaster, his native town, by two Unitarian ministers, pioneers in education, William Henry Herford and David Davis. Thence he went to Owens College, graduating B.A. (London) in 1879. He chose law as his profession, became a partner in the firm of Darbyshire and Tatham in 1889, and continued in partnership until 1923. As a lawyer he was closely associated with R. D. Darbishire in the disposition of Sir Joseph Whitworth's munificent bequests. His chief interests were centred in education and in the religious community in which he was born. He was treasurer of the Widows' Fund Association

(established 1764) from 1901 to 1937, in succession to R. D. Darbishire, one of its greatest benefactors, whose firm had charge of the legal business of the Fund (as it still has) for over a century. A. H. Worthington was also treasurer for many years of the Provincial Assembly of Lancashire and Cheshire, whose origins go back to the seventeenth century; a trustee of Cross Street Chapel, and, in succession to his father, chairman of trustees, resigning in 1931, a Hibbert Trustee from 1902 to 1931, and one of the original proprietors of the *Hibbert Journal*, a governor of Willaston School, and, for many years, a trustee of the Ministers' Stipend Augmentation Fund. He was in succession secretary, chairman, and president of Manchester College, Oxford over a period of forty years.

Owens College and Manchester University he served with a conspicuous fidelity as Clerk of Convocation, 1891—1898, member of the Court of Governors from 1892, and, from 1895 until his death, of the Council, of which he was chairman from September, 1925 until March, 1934. On the occasion of the celebration of the eightieth anniversary of Owens College and of the jubilee of Manchester University in 1930 his long and invaluable services were recognised by the conferment upon him of the honorary degree of LL.D. He bequeathed to the University a considerable sum which will always associate his name with his *alma mater*.

He married Miss Florence Dowson, daughter of the Rev. Henry Dowson, minister of Gee Cross Church for fifty-one years, who in 1917 celebrated his eightieth birthday, his golden wedding, the jubilee of his ministry, and the conferment upon him of the freedom of Hyde in recognition of his services to the town. Mrs. Worthington died in December, 1939.

H. McLACHLAN.

PROCEEDINGS.

1941—1942.

The Wilde Memorial Lecture, held on April 29th, 1941 in the Chemical Theatre of the University, was given by Sir Henry H. Dale, President of the Royal Society, the title being: "A New Era in Medicinal Treatment." Tea and light refreshments were provided in the Staff House of the University before the lecture. (Published Memoir 4, vol. lxxxiv.)

The Annual General Meeting for the session 1940–41 was held on May 20th, 1941, in the Senate Room of the University. A Special Resolution was passed, subject to the approval of the Board of Trade and confirmation at an Extraordinary General Meeting, amending Article 20 of the Articles of Association to read as follows:

> "Every Ordinary Member whose name is on the Register of the Society on the first day of the Financial Year shall pay a subscription for that year and the amount thereof shall be fixed from time to time at the Annual General Meeting of the Society."

An Extraordinary General Meeting was held on September 1st, 1941, in the Geographical Department of the University. The Special Resolution, passed at the Annual General Meeting and since approved by the Board of Trade, was confirmed.

The election of the following new members was confirmed: Dr. Pavel Krug, Mr. H. A. Leech, Mr. C. M. Keyworth, Dr. Wheeler, Miss A. Burton, Miss W. S. Clarke, Mr. Allan Locan, Rev. Dr. McLachlan, Mr. J. Coatman and Mr. A. R. Martin.

Eleven Ordinary Meetings were held during the session, at which lectures were delivered as follows:

1941.

Oct. 7th. "Education for a Civilised World," by Sir Richard Livingstone, President of Corpus Christi College, Oxford.

Oct. 21st. "Manchester after the War," by Alderman Wright Robinson, Lord Mayor-Elect of Manchester.

1941.

Nov. 4th. "Samuel Alexander and his Work," by Professor A. D. Ritchie, University of Manchester. (Published Memoir 6, vol. lxxxiv.)

Nov. 16th. "Some Insects of a Manchester Garden," by Dr. H. W. Miles, Lecturer in Entomology, University of Manchester.

Dec. 2nd. "The Geology of the Oceans," by A. C. Copisarow, Esq.

Dec. 9th. "Colonial Rule in Africa," by W. Fitzgerald, Esq., M.A., Senior Lecturer in Geography, University of Manchester.

1942.

Jan. 20th. "Some Problems of European Population," by Professor H. J. Fleure, President of the Society. (Privately printed.)

Feb. 10th. "Samuel Greg and Styal Mill," by Miss F. Collier, M.A., Tutor, Faculty of Commerce and Administration, University of Manchester. (Published Memoir 10, vol. lxxxv.)

Feb. 24th. "Russia's Changing Farms and Farmers," by Sir John Russell, Director of Rothamsted Experimental Station.

Mar. 10th. "Racial Evolution," by Professor H. J. Fleure, President of the Society.

Mar. 20th. "The Royal Society and its Functions," by Professor A. V. Hill, Secretary of the Royal Society, M.P. for the University of Cambridge.

The Annual General Meeting was held on June 2nd, 1942, in Room No. 7 of the University. Afterwards an Ordinary Meeting was held, when Monsieur Henry Hauck, Director of Labour, Free French Headquarters, London, delivered a lecture on "Paris and its Growth, an interpretation of French Culture."

PROCEEDINGS.

1942—1943.

The Joule Memorial Lecture held on November 10th, 1942, in Room No. 7 of the University, was given by Professor David Brunt, F.R.S., M.A., Sc.D., Imperial College of Science and Technology, the title being "Man and the Weather" (Published Memoir, 4, vol. lxxxv.)

Ten Ordinary Meetings were held during the session, at which lectures were delivered as follows:

1942.

Oct. 13th. "The Warrington Academy and the Literary and Philosophical Society," by the Rev H McLachlan, M.A., D.D., Principal of the Unitarian College, held in Cross Street Chapel Room where the Society held its first meetings. (See pp. 114—128 in "Warrington Academy, its History and Influence," printed for the Chetham Society, 1943.)

Oct. 27th. "Metals," by Sir Lawrence Bragg, O.B.E., M.C., F.R.S., D.Sc., M.A., Director of the Cavendish Laboratory.

At this meeting the President announced the award of the Dalton Medal to Sir Lawrence Bragg.

1943.

Jan. 14th. "Some unpublished Greek Vases," by Professor T. B. L. Webster, M.A. (Published Memoir 3, vol. lxxxv.)

Jan. 19th. "Newton, the man and his influence," by Professor A. D. Ritchie, M.A., Lecture (illustrated by demonstrations) held in conjunction with the University, to celebrate the tercentenary of the birth of Sir Isaac Newton. Exhibition of books in lecture theatre and then until January 30th in the Manchester Museum. (Published Memoir 1, vol. lxxxv.)

1943.

Feb 2nd "A Plan for planning, with special reference to Manchester," by A P Simon, Esq (Published Memoir 5, vol lxxxv)

Feb 16th "The Autonomy of Science," by Professor M Polanyi, M D, Ph D, University of Manchester (Published Memoir 2, vol lxxxv)

Feb 23rd "The Human Senses, especially sight and colour vision," by J H Shaxby Esq, D Sc, University College Cardiff (Published Memoir 6 vol lxxxv)

Mar 2nd "The Historical Method in teaching Science," by Professor J Kenner D Sc Ph D, F R S (Published Memoir 7, vol lxxxv)

Mar 9th "English Romantic Poets and Landscape Painting," by Sir Kenneth Clark, K C B, Director of the National Gallery (Published Memoir 8, vol lxxxv)

Mar 23rd "The Modern Age in Asia," by G F Hudson, Esq, M A, Fellow of All Souls College. (Published Memoir 9, vol lxxxv)

The Annual General Meeting was held in the Geographical Department of the University on Thursday, May 27th, 1943.

ANNUAL REPORT OF THE COUNCIL, APRIL, 1942.

Membership

During the session 1941–42, eight new members were elected, bringing the total number of Ordinary Members to 160, including twelve Life Members and one Student Associate Member There were six resignations during the session, and nine doubtful former resignations confirmed We regret to record the death of three Ordinary Members Mr A H Worthington, Mr. C. F Budenberg and Mr W Burton

Meetings

Details will be found in the record of Proceedings On behalf of the Society, the Council wishes to thank the authorities of Manchester University for their kindness in allowing them the use of their premises for lectures

Society's Accounts

An audited financial statement is attached, together with particulars of assets and liabilities

Gifts

The Council wish to express the Society's thanks to the donors of the following gifts · "The Quarterly Journal of the Royal Meteorological Society," presented by Dr Ashworth , "Memoirs and Proceedings," Vol VI, fourth series, presented by Mr. P. Gaunt , "Check List," Part I, and set of their reports as complete as possible, presented by the Lancashire and Cheshire Fauna Committee

Chemical Section.

No meetings have been held during the past year

Air Raid Loss.

The values of the premises, contents and library have been determined by experts, but the decisions on these values have not, as yet, been communicated to the Society by the Government authorities.

NOTE.—The Treasurer's Accounts of the Session 1941—1942 have been endorsed as follows :

Monday, April 27th, 1942, Audited and found correct.

I have seen the Banker's certificate that they hold £375 of 3½ % War Loan Stock :- £300 of 3½ % War Stock : 1 Bond for £50 and a Bond for £25 3½ % War Loan 1929-47 Inscribed Stock ; and £800 3 % War Stock 1955—1959 ; and the Certificates of the following stocks :—£1,225 Great Western Railway Company's 5 % Consolidated Preference Stock, Nos. 12,293, 12,294 and 12,323 ; £7,500 Gas, Light and Coke Company Ordinary Stock (Nos. 8/1960 and 347,456) ; £100 East India Railway Company £4. 10s. % Annuity Class A Stock (No. 25,656) , £700 4 % Funding Stock, 1960—1990, Nos. 34,185 and 23/3,454 , and the deeds of the Natural History Fund, of the Wilde Endowment Fund, those conveying land on which the Societies' premises stood, and the Declarations of Trust.

Leases and Conveyances dated as follows :—

September 22nd, 1797.
September 23rd, 1797.
December 25th, 1799.
December 25th, 1799.
December 22nd, 1820.
December 23rd, 1820.

Declarations of Trust :—

June 24th, 1801.
December 23rd, 1820.
January 8th, 1878.

Conveyance, relating to the property, 21, Back George Street, Manchester, dated December 7th, 1920.

I have also seen the Dalton and other Medals of the Society.

I have verified the balances of the various accounts with the banker's pass books.

(*Signed*) J. M. NUTTALL.

MANCHESTER LITERARY

R. H. Clayton, Treasurer, in Account with the

DR. **GENERAL**

	£ s d	£ s d
To Balance at Bank, April 1st, 1941		183 11 5
,, Cash in Treasurer's Hands, April 1st 1941		6 5 5
,, Members' Subscriptions —		
Half Rate 1940–42	1 1 0	
Full Rate Arrears	1 1 0	
,, ,, 1940–42	40 19 0	
Half Year 1942–43 (in advance)	10 6	
		43 11 6
,, Dividends —		
Great Western Railway Company's 5 % Consolidated Preference Stock	30 12 6	
East India Railway Company's 4½ % Annuity Class A	3 12 9	
£300 3½ % War Stock	10 10 0	
£75 3½ % War Loan	2 12 6	
		47 7 9
,, Sales of Publications		1 6 6
,, Telephone Rebate		5 10
,, Nature Rebate		16 0
,, Mrs Frail—Half share of Unemployment Card		4 18 7
,, Bank Interest		6 11
		£288 9 11

AND PHILOSOPHICAL SOCIETY.

Society, from April 1st, 1941, to March 31st, 1942

FUND. **CR.**

	£	s.	d	£	s	d
By Charges on Property —						
Chief Rent (Net)				6	9	2
,, House Expenses —						
Gas		16	0			
Black-out	2	15	0			
Office Expenses (1½ years)	16	5	0			
Teas at Meetings	3	1	0			
				22	17	0
,, Administrative Charges —						
National Health Insurance Fund	16	5	6			
State Insurance	4	18	4			
Deed Boxes	3	10	0			
Employers' Liability Insurance		13	6			
Legal Expenses	24	2	8			
Hire of Rooms	6	6	0			
Lecturers' Expenses	15	15	0			
Telephone	2	14	4			
Postage and Carriage	15	1	8			
Printing and Stationery	33	5	11			
Miscellaneous Expenses	8	6	1			
				130	19	0
,, Purchases of Books				2	19	0
,, Return of Overpaid Subscriptions				13	13	0
,, Subscriptions to Societies —						
Royal Entomological Society	2	2	0			
North-Western Naturalists Union		14	0			
Ray Society	1	1	0			
Palæontographical Society	1	1	0			
Malacological Society (2 years)	3	0	0			
Prehistoric Society		15	0			
Lancashire and Cheshire Fauna Committee	1	1	0			
				9	14	0
,, Subscriptions to Journals				26	1	6
,, Bank Charges					8	4
,, Cash in Treasurer's Hands				7	4	10
,, Balance at Bank				68	4	1
				£288	9	11

WILDE ENDOWMENT FUND, 1941–42.

	£	s	d		£	s	d
To Balance at Bank, April 1st, 1941	1,894	12	1	By Assistant Secretary's Salary	104	0	0
,, Bank Interest	2	11	8	,, Lecture Fee	10	10	0
				,, Purchase of 2,000 shares of Gas Light and Coke Company's Ordinary Stock	1,047	3	0
				,, Purchase of £400 3 % War Stock 1955—1959	404	11	0
				Wm Dawson and Sons Ltd (Valuation of Library)	31	10	0
				,, Cash in Treasurer's hands	4	0	0
				,, Balance at Bank March 31st 1942	295	9	9
	£1,897	3	9		£1,897	3	9

BUILDING FUND 1941–42.

	£	s	d		£	s	d
To Balance at Bank, April 1st, 1941	514	7	11	By Purchase of £400 3 % War Stock 1955—1959	404	11	0
,, Rent from property	3	12	3	Balance at Bank March 31st 1942	142	11	0
,, Interest on £700 Funding Loan 4 % Stock	28	0	0				
,, Bank Interest	1	1	10				
	£547	2	0		£547	2	0

JOULE MEMORIAL FUND, 1941–42. (Included in the General Account.)

	£	s	d		£	s	d
To Dividend on £100 East India Railway Company's 4½ % Annuity Class A Stock	3	12	9	By Cash transferred to General Fund	14	2	9
,, Interest on £300 3½ % War Stock	10	10	0				
	£14	2	9		£14	2	9

NATURAL HISTORY FUND, 1941–42. (Included in the General Account.)

	£	s	d		£	s	d
To Dividend on £1,225 Great Western Railway Company's 5 % Consolidated Preference Stock	30	12	6	By Cash transferred to General Fund	30	12	6
	£30	12	6		£30	12	6

Statement relating to the Society's Property as on March 31st, 1942.

Liabilities.	£ s. d.	Assets.	£ s. d.	£ s. d.
		Arrears of Subscriptions, 1940–42	63 0 0	
		,, ,, 1941–42	1 1 0	
				64 1 0
		Cash Balance :—		
		In Bank, Building Fund	142 11 0	
		,, ,, Wilde Fund	295 9 9	
		,, ,, General Fund	68 4 1	
		In Treasurer's hands...	11 4 10	
				517 9 8
				£581 10 8

Investments :—

£7,500 Gas, Light and Coke Company's Ordinary Stock (W.E.F.) ... ...
£400 3 % War Stock, 1955—1959 (W.E.F.) ... ...
£700 4 % Funding Loan (B.F.) ... ...
£400 3 % War Stock, 1955—1959 (B.F.) ... ...
£100 East India Railway Company's 4½ % Annuity Class A (J.M.F.) ... ...
£300 3½ % War Stock (J.M.F.)... ... ...
£1,225 Great Western Railway Company's 5 % Consolidated Preference Stock (Nat. Hist. F.) ... ...
£75 3½ % War Loan Stock, 1929–47 (G.F.) ... ...

Claim to Repayment of Income Tax.

A number of warrants in respect of Dividends and Interest received during the year to April 5th, 1941, were destroyed as a result of enemy action. Copies of these warrants are now being obtained in support of a claim to repayment for 1940–41. In view of the time which has elapsed in obtaining copy warrants it was decided to submit the claim for 1940–41 with that of the year 1941–42. It is estimated that an amount of £120 will be received in respect of the claim for the two years.

ANNUAL REPORT OF THE COUNCIL, APRIL, 1943.

Membership

During the session 1942–43, 23 new members were elected, bringing the total number of Ordinary Members to 169, including twelve Life Members. There were three resignations during the session, and nine doubtful resignations confirmed. We regret to record the death of two Ordinary Members: Mr. J. H. Hindle and Professor R. B. Wild.

Meetings.

Details will be found in the record of Proceedings. On behalf of the Society, the Council wishes to thank the authorities of Manchester University for their kindness in allowing them the use of their premises for lectures.

Society's Accounts.

An audited financial statement is attached together with particulars of assets and liabilities.

Gifts.

The Council wish to express the Society's thanks to the donors of the following gifts: "The Quarterly Journal of the Royal Meteorological Society," presented by Dr. J. R. Ashworth; "Historie of Plants" by John Gerard, 1597, presented by Miss A. C. Alexander; Photograph, Autographed letter and Book Plate of the late Mr. T. A. Coward, President of the Society, 1921–23. Altrincham and District Natural History Society, Proceedings Vol. II,

1923–24, presented by the Lancashire and Cheshire Fauna Committee ; Transactions of the Royal Entomological Society of London, 30 volumes, presented by Major A. W. Boyd ; Faraday's Life and Letters, two volumes, presented by Mr. E. B. Robinson, through Mr W. A. Silvester ; " Carboniferous Flora," 5 volumes, presented by Dr. J. Wilfrid Jackson ; " Memoirs and Proceedings," Vol V, Parts I and II, presented by the Torquay Natural History Society ; 22 volumes including 2 (1789,) 1790, 1793 and 1798, presented by Miss Royle through Dr. J. R Ashworth , Vol. 41, Part IV, 1896—1897, and Vol. 44, Part V, 1899—1900, presented by Dr. J. Wilfrid Jackson , Vols II, III, V, of 1785, 1790 and 1798 respectively, presented by Mr. E. B. Robinson through Mr. W. A. Silvester

Chemical Section.

No meetings have been held during the past year

Air Raid Loss

The values of the premises, contents and library have been determined by experts. The decisions on these values have not, as yet, been communicated to the Society by the Government Authorities, but, during the last few months, the Assessor has been negotiating with the Authorities in London, and it is hoped a decision will soon be arrived at.

MANCHESTER LITERARY

R. H. Clayton, Treasurer, in Account with the

DR. **GENERAL**

	£	s.	d.	£	s.	d.
To Balance at Bank, April 1st, 1942...				68	4	1
,, Cash in Treasurer's Hands, April 1st, 1942 ..				7	4	10
,, Members' Subscriptions :—						
Full Rate Arrears	12	12	0			
,, ,, 1942–43	129	13	6			
				142	5	6
,, Dividends :—						
Great Western Railway Company's 5 % Consolidated Preference Stock... ...	30	12	6			
East India Railway Company's 4½ % Annuity Class A...	3	12	6			
£300 3½ % War Stock	10	10	0			
£75 3½ % War Loan	2	12	6			
				47	7	6
,, Sales of Publications				12	8	10
,, Donations				2	2	0
,, Refund of Income Tax, 1940-41 and 1941-42				58	7	0
,, Bank Interest...					7	4
				£338	7	1

AND PHILOSOPHICAL SOCIETY.

Society, from April 1st, 1942, to March 31st, 1943.

FUND. **CR.**

	£	s.	d.	£	s.	d.
By Charges on Property :—						
Chief Rent (Net) and Income Tax Sch "A"				19	7	2
,, Office Expenses				13	0	0
,, Administrative Charges :—						
State Insurance	4	17	2			
Employers' Liability Insurance		5	10			
Telephone	2	8	11			
Postage and Carriage	14	4	4			
Printing, Stationery and Duplicator ...	29	14	8			
Lecturers' Expenses	21	0	0			
Miscellaneous Expenses	7	10	8			
				80	1	7
,, Printing Memoirs and Proceedings 1939–41				123	18	6
,, Purchases of Books					13	7
,, Repayment on parts of Memoirs and Proceedings				1	10	0
,, Subscriptions to Societies :—						
Palæontographical Society	1	1	0			
Lancashire and Cheshire Fauna Committee	1	1	0			
North-Western Naturalists' Union...		14	0			
North Western Naturalist		15	0			
Ray Society	1	1	0			
Pre-historic Society...		15	0			
				5	7	0
,, Bank Charges and Cheque Book					13	4
,, Cash in Treasurer's Hands				5	4	11
,, Balance at Bank				88	11	0
				£338	7	1

WILDE ENDOWMENT FUND, 1942–43.

	£	s.	d.		£	s.	d.
To Balance at Bank, April 1st, 1942	295	9	9	By Salaries, etc.	104	0	0
,, Cash in Treasurer's Hands	4	0	0	,, Lecture Fee	10	10	0
,, Dividend on £7,500 Gas Light and Coke Company's Ordinary Stock	37	10	0	,, Architect's fee for valuation of George Street Building	20	0	0
,, Interest on £400 3 % War Stock 1955—1959	6	0	0	,, Legal Expenses	10	10	0
,, Income Tax refunded 1940–41 and 1941-42	52	11	10	,, Copies of Library Catalogue	5	0	0
,, Bank Interest		15	1	,, Cash in Treasurer's hands	10	0	0
				,, Cash at Bank	236	6	8
	£396	6	8		£396	6	8

BUILDING FUND 1942–43.

	£	s.	d.		£	s.	d.
To Balance at Bank, April 1st, 1942	142	11	0	By Balance at Bank	176	18	8
,, Interest on £700 Funding Loan 4 % Stock	28	0	0				
,, Interest on £400 3 % War Stock 1955–59	6	0	0				
,, Bank Interest		7	8				
	£176	18	8		£176	18	8

JOULE MEMORIAL FUND, 1942–43. (Included in the General Account.)

	£	s.	d.		£	s.	d.
To Dividend on £100 East India Railway Company's 4½ % Annuity Class A Stock	3	12	6	By Cash transferred to General Fund	14	2	6
,, Interest on £300 3½ % War Stock	10	10	0				
	£14	2	6		£14	2	6

NATURAL HISTORY FUND, 1942–43. (Included in the General Account.)

	£	s.	d.		£	s.	d.
To Dividend on £1,225 Great Western Railway Company's 5 % Consolidated Preference Stock	30	12	6	By Cash transferred to General Fund	30	12	6
	£30	12	6		£30	12	6

Statement relating to the Society's Property as on March 31st, 1943.

LIABILITIES	£ s d	ASSETS	£ s. d.	£ s. d.
		Arrears of Subscriptions, 1940–43	47 5 0	
		" " 1942–43	15 15 0	
				63 0 0
		Cash Balance —		
		In Bank, Building Fund	176 18 8	
		" Wilde Fund	236 6 8	
		" " General Fund	88 11 0	
		In Treasurer's hands	15 4 11	
				517 1 3
				£580 1 3

Investments —

£7 500 Gas Light & Coke Company's Ordinary Stock (W E F)
£400 3 % War Stock 1955—1959 (W E F)
£700 4 %, Funding Loan (B F)
£400 3 % War Stock 1955—1959 (B F)
£100 East India Railway Company's 4½ % Annuity Class A (J M F)
£300 3½ % War Stock (J M F)
£1 225 Great Western Railway Company's 5 % Consolidated Preference Stock (Nat Hist F)
£75 3½ % War Loan Stock, 1929–47 (G F)

A claim for repayment of Income Tax for 1942–43 is now being prepared

NOTE.—The Treasurer's Accounts of the Session 1942—1943 have been endorsed as follows :

Thursday, April 15th, 1943, Audited and found correct.

I have seen the Banker's certificate that they hold £375 of 3½ % War Loan Stock :—£300 of 3½ % War Stock : 1 Bond for £50 and a Bond for £25 3½ % War Loan 1929–47 Inscribed Stock ; and £800 3 % War Stock 1955—1959 ; and the Certificates of the following stocks :—£1,225 Great Western Railway Company's 5 % Consolidated Preference Stock, Nos. 12,293, 12,294 and 12,323 ; £7,500 Gas, Light and Coke Company Ordinary Stock (Nos. 8/1960 and 347,456) ; £100 East India Railway Company £4. 10s. % Annuity Class A Stock (No. 25,656) ; £700 4 % Funding Stock, 1960—1990, Nos. 34,185 and 23/3,454 ; and the deeds of the Natural History Fund, of the Wilde Endowment Fund, those conveying land on which the Societies premises stood, and the Declarations of Trust.

Leases and Conveyances dated as follows :—

September 22nd, 1797.
September 23rd, 1797.
December 25th, 1799.
December 25th, 1799.
December 22nd, 1820.
December 23rd, 1820.

Declarations of Trust :—

June 24th, 1801.
December 23rd, 1820.
January 8th, 1878.

Conveyance, relating to the property, 21, Back George Street, Manchester, dated December 7th, 1920.

I have also seen the Dalton and other Medals of the Society.

I have verified the balances of the various accounts with the banker's pass books.

(*Signed*) J. M. NUTTALL.

THE WILDE LECTURES.

1897. (July 2.) "On the Nature of the Röntgen Rays." By Sir G. G. STOKES, Bart., F.R.S.
1898. (Mar. 29.) "On the Physical Basis of Psychical Events." By Sir MICHAEL FOSTER, K.C.B., F.R.S.
1899. (Mar. 28.) "The newly-discovered Elements; and their relation to the Kinetic Theory of Gases." By Professor WILLIAM RAMSAY, F.R.S.
1900. (Feb. 13.) "The Mechanical Principles of Flight." By the Rt. Hon. LORD RAYLEIGH, F.R.S.
1901. (April 22.) "Sur la Flore du Corps Humain." By Dr. ELIE METCHNIKOFF, For. Mem.R.S.
1902. (Feb 25.) "On the Evolution of the Mental Faculties in relation to some Fundamental Principles of Motion." By Dr. HENRY WILDE, F.R.S.
1903. (May 19.) "The Atomic Theory." By Professor F. W. CLARKE, D.Sc.
1904. (Feb. 23.) "The Evolution of Matter as revealed by the Radio-active Elements." By FREDERICK SODDY, M.A.
1905. (Feb. 28.) "The Early History of Seed-bearing Plants, as recorded in the Carboniferous Flora." Dr. D. H. SCOTT, F.R.S.
1906. (March 20.) "Total Solar Eclipses." By Professor H. H. TURNER, D.Sc., F.R.S.
1907. (Feb. 18.) "The Structure of Metals." By Dr. J. A. EWING, F.R.S., M.Inst.C.E.
1908. (March 3.) "On the Physical Aspect of the Atomic Theory." By Professor J. LARMOR, Sec.R.S.
1909. (Mar. 9.) "On the Influence of Moisture on Chemical Change in Gases." By Dr. H. BRERETON BAKER, F R.S.
1910. (Mar. 22.) "Recent Contributions to Theories regarding the Internal Structure of the Earth." By Sir THOMAS H. HOLLAND, K.C.I.E., D.Sc., F.R.S.

SPECIAL LECTURES

1913. (Mar 4) "The Plant and the Soil" By A D HALL, M A, F R S
1914 (Mar 18) "Crystalline Structure as revealed by X-rays" By Professor W H BRAGG, M A, F R S
1915 (May 4) "The Place of Science in History" By Professor JULIUS MACLEOD D Sc

DALTON LECTURE

1931. (Mar 17) "Atoms and Electrons By Sir JOSEPH J THOMSON O M, D Sc F R S

JOULE MEMORIAL LECTURES

1920. (Dec 14) "The Work and Discoveries of Joule" By Sir DUGALD CLERK K B E, D Sc, F R S
1922 (Dec 5) "The Rise in Motive Power and the Work of Joule" By Sir CHARLES A PARSONS, O M K C B, M A, D Sc, F R S
1924 (Mar 4) "Thermodynamics in Physiology By A V HILL, O B E, M A, Sc D F R S
1928 (Mar 20) "Sub-Atomic Energy" By Professor A S EDDINGTON, M A D Sc, LL D, F R S
1930 (Feb 18) "Science and Problems of the Times" By A P M FLEMING, C B E, M Sc, M I E E
1933 (Mar 14) "The Psychology of Musical Appreciation" By CHARLES S MYERS, C B E, F R S
1934 (Feb 27) "The Expanding Universe as a Thermodynamic System" By Professor E A MILNE, M A, D Sc, F R S
1936 (Feb 11) "The Upper Atmosphere" By Professor E V APPLETON, M A, D Sc, LL D, F R S
1938 (Mar 8) "The Attainment of Low Temperatures" By Dr C G DARWIN, M C, M A, F R S
1940 (Mar 19) "New Applications of Physics to Medicine" By Professor JAS CHADWICK, F R S
1942 (Nov 10) "Man and the Weather" By Professor DAVID BRUNT, F R S, M A, Sc D

WILDE MEMORIAL LECTURES

1926 (Mar. 9.) "Brains of Apes and Men." By G. ELLIOT SMITH, M.A., M.D., F.R.S.

1927 (Mar. 22.) "Physiology of Life in the High Andes." By J. BARCROFT, C.B.E., F.R.S.

1929 (Mar. 19.) "The Nature and Origin of Human Speech." By Sir RICHARD PAGET, Bart.

1932 (Mar. 15.) "Man's Place in Nature as shown by Fossils." By Sir ARTHUR SMITH WOODWARD, LL.D., F.R.S.

1935 (Feb. 12.) "Some Sex Problems in the Fungi." By Professor Dame HELEN GWYNNE VAUGHAN, G.B.E., LL.D., D.Sc., F.L.S.

1937 (Feb. 16.) "Some Problems of the New Stone Age." By HAROLD J. E. PEAKE, M.A., F.S.A.

1939 (Mar. 14.) "Palæolithic Man in the North Midlands." By LESLIE ARMSTRONG, M.C., F.S.I., F.S.A.

1941 (Apr. 29.) "A New Era in Medicinal Treatment." By Sir HENRY H. DALE, President of the Royal Society.

Awards of the Dalton Medal

1898 EDWARD SCHUNCK, Ph.D., F.R.S.

1900 Sir HENRY E. ROSCOE, F.R.S.

1903 Professor OSBORNE REYNOLDS, LL.D., F.R.S.

1919 Professor Sir ERNEST RUTHERFORD, M.A., D.Sc., F.R.S.

1931 Sir JOSEPH J. THOMSON, O.M., D.Sc., F.R.S.

1942 Sir LAWRENCE BRAGG, O.B.E., M.C., F.R.S., D.Sc., M.A.

A detailed list of the medals, awarded to John Dalton and others, which are the property of the Society, will be found in Memoirs and Proceedings, Vol. 84, 1939–41, *pp.* xxxi.–xxxiii.

A DETAILED LIST OF ARTICLES SALVAGED FROM 36, GEORGE STREET, MANCHESTER, AFTER THE DESTRUCTION OF THE BUILDING ON DECEMBER 24TH, 1940, WILL BE FOUND IN *Memoirs and Proceedings*, VOL. 84, 1939–41, *pp.* xxxiv.—xxxvii.

LIST OF PRESIDENTS OF THE SOCIETY.

Date of Election.	
1781.	PETER MAINWARING, M.D., JAMES MASSEY.
1782–1786.	JAMES MASSEY, THOMAS PERCIVAL, M.D., F.R.S.
1787–1789.	JAMES MASSEY.
1789–1804.	THOMAS PERCIVAL, M.D., F.R.S
1805–1806.	REV. GEORGE WALKER, F.R.S.
1807–1809.	THOMAS HENRY, F.R.S.
1809.	*JOHN HULL, M.D., F.L.S
1809–1816.	THOMAS HENRY, F.R.S.
1816–1844.	JOHN DALTON, D.C.L., F.R.S.
1844–1847.	EDWARD HOLME, M.D., F.L.S.
1848–1850.	EATON HODGKINSON, F.R.S., F.G.S.
1851–1854.	JOHN MOORE, F.L.S.
1855–1859.	SIR WILLIAM FAIRBAIRN, Bart., LL.D., F.R.S.
1860–1861.	JAMES PRESCOTT JOULE, D.C.L., F.R.S.
1862–1863.	EDWARD WILLIAM BINNEY, F.R.S., F.G.S.
1864–1865.	ROBERT ANGUS SMITH, Ph.D., F.R.S.
1866–1867.	EDWARD SCHUNCK, Ph.D., F.R.S.
1868–1869.	JAMES PRESCOTT JOULE, D.C.L., F.R.S.
1870–1871.	EDWARD WILLIAM BINNEY, F.R.S., F.G.S.
1872–1873.	JAMES PRESCOTT JOULE, D.C.L., F.R.S.
1874–1875.	EDWARD SCHUNCK, Ph.D., F.R.S.
1876–1877.	EDWARD WILLIAM BINNEY, F.R.S., F.G.S.
1878–1879.	JAMES PRESCOTT JOULE, D.C.L., F.R.S.
1880–1881.	EDWARD WILLIAM BINNEY, F.R.S., F.G.S.
1882–1883.	SIR HENRY ENFIELD ROSCOE, D.C.L., F.R.S.
1884–1885.	WILLIAM CRAWFORD WILLIAMSON, LL.D., F.R.S.
1886.	ROBERT DUKINFIELD DARBISHIRE, B.A., F.G.S.
1887.	BALFOUR STEWART, LL.D., F.R.S.
1888–1889.	OSBORNE REYNOLDS, LL.D., F.R.S.
1890–1891.	EDWARD SCHUNCK, Ph.D., F.R.S.

* Elected April 28th; resigned office May 5th.

Date of Election.

1892-1893.	ARTHUR SCHUSTER, Ph.D., F.R.S.
1894-1896.	HENRY WILDE, D.C.L., F.R.S.
1896.	EDWARD SCHUNCK, Ph.D., F.R.S.
1897-1899.	JAMES COSMO MELVILL, M.A., F.L.S.
1899-1901.	HORACE LAMB, M.A., F.R.S.
1901-1903.	CHARLES BAILEY, M.Sc., F.L.S.
1903-1905.	W. BOYD DAWKINS, M.A., D.Sc., F.R.S.
1905-1907.	SIR WILLIAM H. BAILEY, M.I.Mech.E.
1907-1909.	HAROLD BAILY DIXON, M.A., F.R.S.
1909-1911.	FRANCIS JONES, M.Sc., F.R.S.E.
1911-1913.	F. E. WEISS, D.Sc., F.L.S.
1913-1915.	FRANCIS NICHOLSON, F.Z.S.
1915-1917.	SYDNEY J. HICKSON, M.A., D.Sc., F.R.S.
1917-1919.	WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C.
1919.	G. ELLIOT SMITH, M.A., M.D., F.R.S.
1919-1921.	SIR HENRY A. MIERS, M.A., D.Sc., F.R.S.
1921-1923.	T. A. COWARD, M.Sc., F.Z.S., F.E.S.
1923-1925.	H. B. DIXON, C.B.E., M.A., Ph.D., M.Sc., F.R.S., F.C.S.
*1925.	REV. A. L. CORTIE, S.J., D.Sc., F.R.A.S., F.Inst.P.
1925-1927.	H. LEVINSTEIN, D.Sc., M.Sc., F.I.C.
1927-1929.	W. L. BRAGG, O.B.E., M.A., F.R.S.
1929-1931.	C. E. STROMEYER, O.B.E., M.Inst.C.E.
1931-1933.	B. MOUAT JONES, D.S.O., M.A.
1933-1935.	JOHN ALLAN, F.C.S.
1935-1937.	R. W. JAMES, M.A., B.Sc.
1937-1939.	R. H. CLAYTON, M.Sc.
1939-1940.	D. R. HARTREE, M.A., Ph.D., M.Sc., F.R.S.
1940	H. J. FLEURE, M.A., D.Sc., F.R.S.

LIST OF HONORARY MEMBERS OF THE SOCIETY.

Date of Election.

Apr. 26th, 1892.	C. LIEBERMANN.
Apr. 17th, 1894.	A. GOUY.
do.	SIDNEY VINES.
do.	EMIL WARBURG.

* Died May 16th, 1925.

Date of Election.	
Apr. 30th, 1895.	SIR JOSEPH JOHN THOMSON, O.M
Apr. 24th, 1900.	SIR J. ALFRED EWING.
do.	ANDREW RUSSELL FORSYTH.
do.	ROBERT RIDGEWAY.
May 13th, 1902.	SIR JOSEPH LARMOR.
do.	SIR OLIVER LODGE.
Apr. 28th, 1903.	FRANK WIGGLESWORTH CLARKE
Apr. 5th, 1910.	WALTHER NERNST.
Nov. 28th, 1922.	NIELS BOHR.
Apr. 13th, 1926.	SAMUEL ALEXANDER, O.M.
do.	ARNOLD SOMMERFELD.
Nov. 16th, 1926.	SIDNEY J. HICKSON.
do.	SIR HENRY A. MIERS.
May 13th, 1930.	F. E. WEISS.

LIST OF CORRESPONDING MEMBERS OF THE SOCIETY.

Date of Election.	
Feb. 3rd, 1920.	WILLIAM SALVADOR CURPHEY.
Nov. 1st, 1921.	MRS. C. W. PALMER.
Nov. 29th, 1923	H. F. COWARD.
Apr. 1st, 1924.	GILBERT J. FOWLER.
Dec. 16th, 1924.	G. SENN.
Oct. 13th, 1925.	H. G. A. HICKLING.
Nov. 11th, 1941.	MISS E. OWEN.

THE COUNCIL

OF THE

MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

FOUNDED 1781.

Elected May 20th, 1941.

President. H. J. Fleure, M.A., D.Sc., F.R.S.

Vice-Presidents: D. R. Hartree, M.A., Ph.D., M.Sc., F.R.S., D. M. Paul, B.Sc., A.I.C., T. B. L. Webster, M.A.

Secretaries: P. Guthlac Jones, Miss C. M. Legge, M.A., A.R.C.A.

Treasurer: R. H. Clayton, M.Sc.

Librarians: W. H. Brindley, M.C., M.A., M.Sc., Ph.D., G. N. Burkhardt, M.Sc., Ph.D., F.I.C.

Curator: J. R. Ashworth, D.Sc.

Council: G. E. Archer, M.B., Ch.B., D.L.O., F.R.C.S.E., J. D. Chorlton, M.Sc., G. W. Cussons, H. Hayhurst, F.I.C., A.M.I.Chem.E., Alex R. Todd, D.Sc., Dr.Phil. Nat., D. Phil., F. C. Toy, D.Sc., D. E. Wheeler, B.Sc., Ph.D., Miss Grace Wigglesworth, M.Sc.

Assistant Secretary and Librarian: W. Coventry.

THE COUNCIL

OF THE

MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY

FOUNDED 1781.

Elected June 2nd, 1942

President: H. J. Fleure, M.A., D.Sc., F.R.S.

Vice-Presidents: G. E. Archer, M.B., Ch.B., D.L.O., F.R.C.S.E., D. R. Hartree, M.A., Ph.D., M.Sc., F.R.S., F. C. Toy, D.Sc., T. B. L. Webster, M.A.

Secretaries: P. Guthlac Jones, Miss C. M. Legge, M.A., A.R.C.A.

Treasurer: R. H. Clayton, M.Sc.

Librarians: W. H. Brindley, M.C., M.A., M.Sc., Ph.D., G. N. Burkhardt, M.Sc., Ph.D., F.I.C.

Curator: J. R. Ashworth, D.Sc.

Council: Miss A. C. Alexander, B.Sc., W. Ll. Bullock, M.A., Ph.D., J. D. Chorlton, M.Sc., R. P. Foulds, M.Sc., F.I.C., F.T.I., H. Hayhurst, F.I.C., A.M.I.Chem.E., J. Kenner, D.Sc., Ph.D., F.R.S., Rev. A. McLachlan, M.A., D.D., A. R. Todd, D.Sc., Dr.Phil. Nat., D.Phil., D. E. Wheeler, B.Sc., Ph.D.

Assistant Secretary and Librarian: W. Coventry.

THE COUNCIL

OF THE

MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY

FOUNDED 1781

Elected May 27th, 1943.

President.

H. J. FLEURE, M.A., D.Sc., F.R.S.

Vice-Presidents.

G. E. ARCHER, M.B., Ch.B., D.L.O., F.R.C.S.E.
D. R. HARTREE, M.A., Ph.D., M.Sc., F.R.S.
F. C. TOY, D.Sc.
T. B. L. WEBSTER, M.A.

Secretaries.

Miss C. M. LEGGE, M.A., A.R.C.A.
D. E. WHEELER, B.Sc., Ph.D.

Treasurer.

R. H. CLAYTON, M.Sc.

Librarians.

W. H. BRINDLEY, M.C., M.A., M.Sc., Ph.D.
Rev. H. McLACHLAN, M.A., D.D.

Curator.

J. R. ASHWORTH, D.Sc.

Other Members of the Council.

Miss A. C. ALEXANDER, B.Sc.
W. Ll. BULLOCK, M.A., Ph.D.
J. D. CHORLTON, M.Sc.
H. HAYHURST, F.I.C., A.M.I.Chem.E.
G. N. BURKHARDT, M.Sc., Ph.D., F.I.C.
P. GUTHLAC JONES.
J. KENNER, D.Sc., Ph.D., F.R.S.
W. A. SILVESTER, M.Sc.
A. R. TODD, D.Sc., Dr.Phil. Nat., D.Phil.

Assistant Secretary and Librarian.

W. COVENTRY.

LIST OF SOCIETIES AND INSTITUTIONS

TO WHICH THE *Memoirs and Proceedings* ARE SENT

Societies and Institutions present their publications to the Society's Library with the exception of those marked with a dagger (†)

Aberystwyth †National Library of Wales
Abo Akademie Bibliotek
Adelaide Royal Society of South Australia South Australian Museum Public Library Museum and Art Gallery of South Australia
Amsterdam Koninklijke Akademie van Wetenschappen Société Mathematique Bibliothek van het Wickundig en Genootschap
Auckland The Auckland Institute and Museum
Augsburg Der naturwissenschaftliche Verein fur Schwaben

Baltimore Johns Hopkins University
Bamberg Naturforschende Gesellschaft
Bangalore (Madras) Indian Institute of Science
Basle Naturforschende Gesellschaft Naturforsch Gesellsch Universitats-Bibliothek Helvetica Chimica Acta
Batavia Natuurkundige Vereeniging in Nederlandsch-Indie Bataviaasch Genootschap van Kunsten en Wetenschappen
Bath Bath and West and South Counties Society
Belgrade Académie Royale Serbe
Belfast Naturalists' Field Club
Bergen Geofysick Institute
Berkeley University of California
Berlin Deutsche chemische Gesellschaft Preussische Geologische Landesanstalt Preussische Akademie der Wissenschaften Gesellschaft der Naturforschender Freunde
Besançon Société d'émulation de Doubs
Birmingham Natural History and Philosophical Society
Bloemfontein National Museum

Bologna Reale Accademia delle Scienze dell'Istituto
Bombay Branch of the Royal Asiatic Society of Bengal
Bonn Naturhistorischer Verein der preussischen Rheinlande und Westfalens
Bordeaux Société des Sciences physiques et naturelles
Boston American Academy of Arts and Sciences Society of Natural History
Boulder University of Colorado
Bremen Naturwissenschaftlicher Verein
Brisbane Royal Geographical Society of Australasia Queensland Museum Royal Society of Queensland
Bristol Naturalists Society
Brno Faculty of Science Masaryk University
Brooklyn (N Y) Institute of Arts and Sciences
Brussels Académie Royale de Belgique Musée Royal d'Histoire Naturelle de Belgique Société Belge de Géologie Paléontologie et Hydrologie
Buckhurst Hill Essex Field Club
Buenos Aires Sociedad Cientifica Argentina
Buffalo Society of Natural Sciences

Caen Academie nationale des Sciences, Arts et Belles-Lettres †Société Linnéenne de Normandie
Calcutta Agricultural Research Institute (Pusa) Geological Survey of India Indian Association for the Cultivation of Science Meteorological Department of India (Poona) Royal Asiatic Society of Bengal
Cambridge Philosophical Society †University Library
Cambridge (Mass) Harvard College †Massachusetts Institute of Technology Library
Canberra National Library
Cape Town Royal Society of South Africa South African Museum
Cardiff Naturalists' Society
Catania Accademia Gioenia di Scienze naturali
Chambery Académie des Sciences Belles-Lettres et Arts de Savoie
Changsa Geological Survey of China
Chapel Hill Elisha Mitchell Scientific Society

Charlottenburg. Physikalisch-Technische Reichsanstalt.

Cherbourg. Société nationale des Sciences naturelles.

Chicago. Astrophysical Journal. Field Museum of Natural History. University of Chicago Library.

Cincinnati. Lloyd Library and Museum. †American Association for the Advancement of Science. Society of Natural History.

Clermont-Ferrand. La Société des amis de l'Université de Clermont.

Colorado Springs. Colorado College. Coburn Library.

Columbia. University of Missouri.

Columbus. Ohio Journal of Science. Ohio State University.

Copenhagen. Kongelige Danske Videnskabernes Selskab. Kongeligt Nordisk Oldskrift Selskab. Naturhistorisk Forening.

Cracow. Société Polonaise Mathématique.

Cullercoats. See Newcastle-upon-Tyne.

Danzig. Naturforschende Gesellschaft. Westpreussischer Botanisch-Zoologischer Verein.

Davenport. Academy of Natural Sciences.

Delft. Technische Hoogeschool.

Dijon. Académie des Sciences, Arts et Belles-Lettres.

Dorpat. Naturforschende Gesellschaft. Universitas Tartuensis.

Douai. Société d'Agriculture, Sciences et Arts du Département du Nord.

Draguignan. Société d'études scientifiques et archéologiques.

Dublin. †National Library of Ireland. Royal Dublin Society. Royal Irish Academy. †Trinity College Library.

Dunkerque. Société Dunkerquoise pour l'encouragement des Sciences.

Durban. †Corporation Museum.

Edinburgh. Botanical Society. Geological Society. Mathematical Society. †National Library of Scotland. Royal Botanic Gardens. Royal Observatory. Royal Physical Society. Royal Society. Royal Scottish Society of Arts. †Scottish Meteorological Society. University Library.

Elberfeld. Naturwissenschaftlicher Verein.
Epinal. Société d'émulation des départements des Vosges.
Erlangen. Physikalisch-medizinische Societät.
Evreux. Société libre d'Agriculture, Sciences, Arts et Belles Lettres de l'Eure.

Falmouth. Royal Cornwall Polytechnic Society.
Florence (Firenze). Biblioteca Nazionale Centrale.
Frankfurt am Main. Physikalischer Verein; Senckenbergische Naturforschende Gesellschaft.
Freiburg i. Br. Naturforschende Gesellschaft.

Geneva. Institut national Genevois; Société de Physique et d'Histoire Naturelle. See also Basle.
Genova. Museo Civico di Storia Naturale.
Giessen. Oberhessische Gesellschaft für Natur und Heilkunde.
Glasgow. Geological Society; Glasgow and Andersonian Natural History and Microscopical Society; Royal Philosophical Society; †University Library.
Görlitz. Naturforschende Gesellschaft.
Göteborg. Göteborgs Stadtsbibliotek (Högskola).
Göttingen. Gesellschaft der Wissenschaften.
Grahamstown. Albany Museum.
Granville. Denison University.
Graz. Verein der Aertze in Steiermark.
Greenwich. Royal Observatory.

Haarlem. Hollandsche Maatschappij der Wetenschappen; Musée Teyler; Nederlandsche Maatschappij ter bevordering van Nijverheid; Geologisch Bureau van het Nederlandsch Mijngebied.
Halifax, N.S. Nova Scotian Institute of Science.
Halle. Akademie der Naturforscher; Naturforschende Gesellschaft und naturwissenschaftlicher Verein.
Hamburg. Naturwissenschaftlicher Verein; Mathematische Gesellschaft.
Hanley. See Stoke-on-Trent.
Hanover. Naturhistorische Gesellschaft.
Hartford (Conn.). Connecticut State Library (Geological and Natural History Survey).

Heidelberg Badische Sternwarte Naturhistorischmedizinischer Verein

Helsingfors Finska Vetenskaps Societeten Societas pro Fauna et Flora Fennica

Hermannstadt Siebenburgischer Verein fur Naturwissenschaften

Hobart Royal Society of Tasmania

Hong Kong Royal Observatory

Hull †Scientific and Field Naturalists' Club †Yorkshire Naturalists' Union

Indianapolis Department of Geology and Natural Resources of Indiana

Iowa City Iowa State University Iowa Geological Survey

Ithaca Cornell University Agricultural Experimental Station

Johannesburg South African Association for the Advancement of Science

Kazan Imperial University Society of Archaeology

Kiel Naturwissenschaftlicher Verein fur Schleswig-Holstein Institut fur Meereskunde der Universitat Kiel

Kiev Academy of Sciences of the Ukrainian Soviet Socialistic Republic The Academy Institute for Physical Chemistry

Kodaikanal See Madras

Konigsberg i Pr Universitats Sternwarte Physikalisch-okonomische Gesellschaft

Kyoto College of Science and Engineering, Imperial University

Lausanne Société Vaudoise des Sciences Naturelles

Lawrence Kansas University

Leeds Geological Association Philosophical and Literary Society Yorkshire Geological Society

Leeuwarden Friesch Genootschap, van Geschied-, Oudheid -en Taalkunde

Leicester Literary and Philosophical Society

Leiden. Maatschappig der Nederlandsch Letterkunde. Rijks Geologisch- Mineralogisch Museum. Rijks Herbarium. Société Néerlandaises de Zoologie.

Leipzig. Naturforschende Gesellschaft. Jablonowskische Gesellschaft. Sächsische Gesellschaft der Wissenschaften.

Le Mans. Société d'Agriculture, Sciences et Arts de la Sarthe.

Lemberg. Bibliothek der Sevcenk Gesellschaft.

Leningrad. Academy of Sciences of the Union of Socialist Soviet Republics

Liége. Société Géologique de Belgique. Société Royale des Sciences.

Lille. Société des Sciences d'Agriculture et des Arts. L'Universitaire.

Lima, Peru. Cuerpo de Inginieros de Minas del Peru.

Lincoln, U S.A Nebraska Geological Survey University of Nebraska.

Lisbon. Observatorio Central Meteorologico. Observacões meteorologicas da Madeira.

Liverpool. Biological Society. Engineering Society. Geological Society. Hartley Botanical Laboratories Literary and Philosophical Society.

London. British Association. British Museum (Natural History). British Museum (Library of Pure and Applied Science). British Museum Copyright Office. Chemical Society. Faraday Society. Geological Society. Institution of Civil Engineers. Institution of Electrical Engineers. Institution of Mechanical Engineers. Linnean Society. Mathematical Society. Meteorological Office. National Central Library. Patent Office. Physical Society. Quekett Microscopical Society. Royal Society. Royal Astronomical Society. Royal Geographical Society. Royal Horticultural Society. Royal Institute of British Architects. Royal Institution of Great Britain. Royal Meteorological Society. Royal Observatory. Royal Society of Arts. †Subject Index to Periodicals. University Library. Zoological Society.

Lucca. Reale Accademia Lucchese di Scienze, Lettere, ed Arti.

Lund. The University Library.

Luxembourg. Institut Grand Ducal de Luxembourg.

Lwow See Lemberg

Lyon Académie des Sciences L'Université

Madison Wisconsin Academy of Sciences Arts and Letters, Wisconsin Geological and Natural History Survey

Madras Observatory (Kodaikanal) University

Madrid Academia de Ciencias Sociedad Matematica Española

Manchester Association of Engineers †Chetham's Library †Christie Library Conchological Society Geographical Society Geological Association Microscopical Society †Municipal College of Technology †Central Library Shirley Institute Statistical Society Textile Institute

Manhattan Library of Kansas State College of Agriculture and Applied Science

Manila Bureau of Science Ethnological Survey

Marburg Gesellschaft zur Beförderung der gesammten Naturwissenschaften

Marseilles Faculté des Sciences de l'Université

Melbourne Royal Society of Victoria

Metz Académie de Metz

Mexico Instituto Geologico Academia Nacional de Ciencias "Antonio Alzate"

Middleburg Zeeuwsch Genootschap der Wetenschappen

Milan Reale Istituto Lombardo di Scienze e Lettere Reale Osservatorio di Brera in Milano (Merati Como) Societa Italiana di Scienze Naturali, e Museo Civico

Minneapolis University of Minnesota †Academy of Natural Sciences

Missoula University of Montana

Modena Regia Accademia di Scienze, Lettere ed Arti

Montevideo Museo de Historia Natural

Montpellier Académie des Sciences et Lettres

Moscow Société des Naturalistes de Moscou

Munich Bayerische Akademie der Wissenschaften

Nancy. Société des Sciences de Nancy.

Naples. Accademia delle Scienze fisiche e matematiche. Accademia di Archeologia Lettere e Belle Arti. Società Reale di Scienze.

Neuchâtel. Société neuchâteloise des Sciences naturelles.

Newcastle upon Tyne. Dove Marine Laboratories, Cullercoats. †Literary and Philosophical Society. Natural History Society of Northumberland and Durham and Newcastle-upon-Tyne. University of Durham Philosophical Society.

New Haven (Conn.). Connecticut Academy of Arts and Sciences. Bingham Oceanographic Collection.

New York. Academy of Sciences. American Chemical Society. American Mathematical Society. American Museum of Natural History. Meteorological Observatory (Central Park). The Vanderbilt Marine Museum.

Nimes. Académie de Nimes.

Norman. Oklahoma Academy of Science.

Norwich. Norfolk and Norwich Naturalists Society.

Offenbach. Der Offenbacher Verein für Naturkunde.

Oporto. Academica Polytechnica Porto.

Oslo. Norske Videnskaps Akademie. Norsk Meteorologisk Institut. Observatorium. Bibliothèque de l'Université Royale de Norvège.

Ottawa. Dominion Astrophysical Observatory. Geological Survey of Canada. Royal Society of Canada.

Oxford. †Bodleian Library. Radcliffe Library.

Palermo. Reale Accademia di Scienze Lettere e Belle Arti.

Paris. Académie des Sciences. École nationale supérieure des Mines. École polytechnique. Muséum d'Histoire naturelle.

Peiping. Geological Society of China.

Philadelphia. Academy of Natural Sciences. American Philosophical Society. Franklin Institute. †Philadelphia Commercial Museum. Wagner Free Institute of Science.

Pietermaritzburg. †Government Geologist, Surveyor General's Office. Natal Government Museum.

La Plata. Direccion General de Estadistica de la Prov. Buenos Aires. Universidad Nacional Facultad de Ciencias Fisico-Matematicas.

Plymouth. Plymouth Institution and Devon and Cornwall Natural History Society.

Poona. (See Calcutta.)

Portici. Laboratorio di Zoologia generale e agraria, R. Scuola sup. di Agricoltura.

Prague. Böhmische Gesellschaft der Wissenschaft.

Pretoria. The University.

Puget Sound. See Seattle.

Pusa. See Calcutta.

Rennes. Société Scientifique de Bretagne.

Rheims. Académie nationale.

Riga. Naturforscher Verein.

La Rochelle. Société des Sciences naturelles de la Charente inférieure.

Rochdale. Literary and Scientific Society.

Rochester, N.Y. Academy of Science.

Rock Island. Augustana College Library.

Rome. Institut International d'Agriculture. Reale Accademia dei Lincei. Società Italiana per il progresso delle Scienze. Vatican Observatory (Specola Vaticana).

Rostock. Verein der Freunde der Naturgeschichte in Mecklenburg.

Rouen. Académie des Sciences.

Sacramento. See Berkeley.

St. Louis. Missouri Botanical Garden. †Academy of Science. The Washington University.

St. Paul. See Minneapolis.

Salford. †Royal Museum and Library.

San Diego. Society of Natural History.

San Francisco. California Academy of Sciences.

Santiago. Deutscher wissenschaftlicher Verein.

Sassari. Regia Università Istituto Fisiologico.

Seattle. University of Washington. Oceanographical Laboratories. Puget Sound Marine Biological Station.

Sendai. Tohoku Imperial University.

Sheffield. Midland Institute of Mining, Civil and Mechanical Engineers. Safety in Mines Research Board Laboratories.

Shrewsbury. Caradoc and Severn Valley Field Club.

Simla. See Calcutta
Southport. Fernley Observatory
Stockholm. Entomologiska Föreningen Kongeliga Svenska Vetenskaps-Akademi Royal Library Sveriges Geologiska Undersökning
Stoke-upon-Trent North Staffordshire Field Club
Stratford. The Essex Field Club.
Swansea. Scientific and Field Naturalists' Society
Sydney. Australian Museum. Linnean Society of New South Wales. Royal Society of New South Wales.

Tashkent L'Université de l'Asie Centrale
Taihoku Imperial University
Tartu See Dorpat.
Teddington National Physical Laboratory
Tiflis Geophysikalisches Observatorium Georgiens
Tokyo Faculty of Science, Imperial University of Tokyo. Imperial Academy. Institute of Electrical Engineers of Japan. Institute of Physical and Chemical Research Physico-Mathematical Society of Japan. National Research Council of Japan.
Toronto. University Library.
Toulouse. Académie des Sciences, Inscriptions, et Belles-Lettres.
Trondhjem. Kongelige Norske Videnskabers Selskab Museet
Troyes Société Académique d'Agriculture de l'Aube.
Tufts, Massachusetts. Tufts College.

Uccle. L'Observatoire royale et l'Institut royal Météorologique de Belgique.
Ukraine. (See Kiev.)
Upsala. Kongeliga Universitet. Kongeliga Vetenskaps-Societeten.
Urbana. Illinois State Geological Survey. Illinois State Laboratory of Natural History. University of Illinois.
Utrecht. Koninklijk Nederlandsch Meteorologisch Instituut. Provincial Utrechtsch Genootschap van Kunsten en Wetenschappen.

Venice Reale Istituto Veneto di Scienze, Lettere, ed Arti
Victoria, B C. Dominion Astrophysical Observatory
Vienna Akademie der Wissenschaften Universitats-Sternwarte Naturhistorisches Museum Zoologisch-Botanische Gesellschaft Oesterreichische Gesellschaft fur Meteorologie

Washington University See St Louis, Mo
Washington, University of See Seattle
Washington, D C Bureau of Standards, Dept of Commerce and Labor Carnegie Institute Smithsonian Institution, Bureau of Ethnology Smithsonian Institution, United States National Museum U S Coast and Geodetic Survey U S Department of Agriculture U S Geological Survey U S Naval Observatory †U S Patent Office
Watford Hertfordshire Natural History Society and Field Club
Wellington, N Z Royal Society of New Zealand
Wiesbaden Nassauischer Verein fur Naturkunde
Wurzburg Physikalisch-medizinische Gesellschaft

York Yorkshire Philosophical Society

Zurich Naturforschende Gesellschaft Schweizerischer Meteorologische Central-Anstalt

LIST OF ORDINARY MEMBERS OF THE SOCIETY, MAY, 1943.

* *Members who have died during the last two Sessions.*

Year of Election.

1928. Eric Ahlquist, The Croft, Ladybrook Road, Bramhall Park, Cheadle Hulme, Cheshire.

1920. Miss A. C. Alexander, B.Sc., c/o Messrs. Tootal Broadhurst Lee Co Ltd., 56, Oxford Street, Manchester, 1.

1920. John Allan, F.C.S., 18, Moorfield Road, West Didsbury, Manchester, 20.

1922. J. T. Allpass, 34, Roxton Road, Heaton Chapel, Stockport.

1942. Dr. Alexander Altmann, 38, Waterpark Road, Salford, 7.

1921. W. Anderson, B.Sc., The College of Technology, Manchester, 1.

1928. G. E. Archer, M.B., Ch.B., D.L.O., F.R.C.S.(Ed.), West Thorpe, Park Road, Bowdon, Cheshire.

1943. A. Leslie Armstrong, 20, Princess Street, Manchester.

1926. J. R. Ashworth, D.Sc., 55, King Street South, Rochdale.

1920. F. W. Bailey, Haven House, Broadbottom, Cheshire.

1936. Bernard Bann, M.Sc., A.I.C., 3, Wellington Grove, Stockport.

1940. Mrs. E. A. Bardsley, 17, Queens Road, Oldham.

1938. F. H. Bentley, M.B., F.R.C.S., 1, Lorne Street, Upper Brook Street, Manchester, 13.

1919. W. H. Bentley, D.Sc., F.C.S., Logan Rock, 188, Birkenhead Road, Meols, Wirral, Cheshire.

1937. Professor P. M. S. Blackett, M.A., F.R.S., St. Clare, Park Avenue, Ruislip, Middlesex.

1920. R. W. Blakeley (Life Member), 299, Great Clowes Street, Salford, 7.

1914. Frank Bowman, M.A., M.Sc.Tech., 12, Clifton Avenue, Fallowfield, Manchester, 14.

1914. Major A. W. Boyd, M.C., M.A., F.R.E.S., Frandley House, Near Northwich.

Year of Election.

1928. A. J. Bradley, M.Sc., Ph.D., The Cavendish Laboratory, Cambridge.
1927. J. Crighton Bramwell, M.A., M.D., F R C.P , 15, Lorne Street, Manchester, 13
1927 J. C M Brentano, D.Sc., 11, Rathen Road, Manchester, 20.
1936. W. H. Brindley, M.C., M.A., M.Sc., Ph.D., 11, Pikes Lane, Glossop, Derbyshire.
1938. F. J. Brown, M.Sc., The University, Manchester, 13.
1936. J. P. Brown, B.Sc., Brockley Villas, Little Hulton, Nr. Bolton
1934. Ernest Brunner, Ph.D., 52, Daisy Bank Road, Victoria Park, Manchester, 14.
1929. H. E. Buckley, D.Sc., Bradda, Hazelhurst Road, Worsley, Lancs.
1889. *C. F Budenberg, M.Sc., M.I.Mech.E., Somerville, Arkwright Road, Marple, Cheshire.
1936. Professor W. Ll. Bullock, M.A., Ph.D., Arborfield, Langham Road, Bowdon, Cheshire.
1925. G. N. Burkhardt, M.Sc., Ph.D., F.I.C., The University, Manchester, 13.
1941. Miss A. Burton, Stethos House, 68, Sackville Street, Manchester, 1.
1894. *W. Burton, M.A., F.C.S., 8, Primrose Hill Road, London, N.W.3.
1920. Miss Marion Chadwick, M.Sc.Tech., 1, Didsbury Road, Stockport.
1899. D. L. Chapman, M.A., F.R.S., Jesus College, Oxford.
1943. Socrates Emanuel Chiotides, 29, Minshull Street, Manchester, 1.
1929. J. D. Chorlton, M.Sc., 63, Palatine Road, Withington, Manchester, 20.
1941. Miss W. S. Clarke, The University, Manchester, 13.
1939. G. F. Clayton, 1, Parkfield Road, Didsbury, Manchester.
1929. J. H. Clayton, Lymm Hall, Lymm, Cheshire.
1920. R. H. Clayton, M.Sc., 1, Parkfield Road, Didsbury, Manchester, 20.

Year of Election.

1922. Miss Gladys Clegg, M.Sc., 28, Winwood Road, East Didsbury, Manchester, 20.

1941. John Coatman, C.I.E., M.A., c/o The Firs, Fallowfield, Manchester, 14

1928. A. F. Core, M.Sc., The University, Manchester, 13.

1928. C. G. Core, M.Sc., The University, Manchester, 13.

1938. T. G. Cowling, M.A., D.Phil., The University, Manchester, 13.

1934. Miss R. E. S. Cox, The Bungalow, Park Road, Monton, Nr. Manchester.

1916. Mrs. M. B Craven, M.Sc.Tech. (Life Member), College of Technology, Manchester, 1.

1919. Miss Mary Cunningham, D.Sc., 27, Clarence Terrace, Bollington, Nr. Macclesfield.

1923. George W. Cussons, The Technical Works, Lower Broughton, Manchester, 7.

1929. J. A. Darbyshire, M.Sc., Melandra House, Kershaw Street, Failsworth, Manchester.

1942. Miss Lois Dickinson, Public Health Laboratory, York Place, Manchester, 13.

1918. Miss Annie Dixon, M.Sc., F.R.M.S., (Life Member), Kauguri, Batchwood Drive, St. Albans.

1930. Professor J. M. F. Drummond, M.A., F.R.S.E., 87, Wellington Road, Fallowfield, Manchester, 14.

1941. Morris Feinmann, 18, Roston Road, Salford, 7.

1942. W. R. Fielding, M.A., M.Sc., M.Ed., Manor House, Manor Road, Fleetwood.

1924. A. P. M. Fleming, C.B.E., M.Sc.Tech., M.I.E.E., Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.

1932. Professor H. J. Fleure, M.A., D.Sc., F.R.S., 123, Lapwing Lane, Didsbury, Manchester, 20.

1940. R. P. Foulds, M.Sc., F.I.C., F.T.I., c/o Messrs. Tootal Broadhurst Lee Co. Ltd., 56, Oxford Street, Manchester, 1.

Year of Election.

1922. P. Gaunt, A.I.C., Lawnhurst, Didsbury, Manchester, 20.

1922. A. Gill, B.Sc., A.I.C., Hardwick, 30, Woodhill Drive, Prestwich, Nr. Manchester.

1926. W. Howard Goulty (Life Member), 6, Brown Street, Manchester, 2.

1929. Professor D. R. Hartree, M.A., Ph.D., F.R.S. (Life Member), 1, Didsbury Park, Didsbury, Manchester, 20.

1924. H. Hayhurst, F.I.C., A.M.I.Chem.E., Fouray, Parkfield Road, Didsbury, Manchester, 20.

1924. Mrs. H. Hayhurst, M.Sc., Fouray, Parkfield Road, Didsbury, Manchester, 20.

1921. D. C. Henry, M.A., The University, Manchester, 13.

1919. D. M. Henshaw, c/o Messrs. W. C. Holmes & Co. Ltd., Engineers, Huddersfield.

1928. J. B. M. Herbert, M.Sc., The University, Manchester, 13.

1942. Dr. D. H. Hey, 49, Knutsford Road, Wilmslow, Cheshire

1940. W. Fenton Higgins, Broadmead, Broad Lane, Hale, Cheshire.

1943. Allan Howard Hilton, 135, Great Clowes Street, Manchester, 7.

1926. *John H. Hindle, F.R.A.S., Union Engineering Works Witton, Blackburn.

1936. K. G. Holden, B.A., Northlea, Altrincham, Cheshire.

1936. N. N. Holden, Braeside, Altrincham, Cheshire.

1943. Ernest Hollings, Dunleath, 17, Alexandra Road, Sale, Cheshire.

1920. T. Horner, M.Sc.Tech., A.I.C., (Life Member), c/o The District Bank, Dalaunay Road, Crumpsall, Manchester, 8.

1926. O. R. Howell, B.Sc., Ph.D., Spey Lodge, 29, Palatine Road, Withington, Manchester, 20.

1909. Frederick Howles, D.Sc., Glenluce, Waterpark Road, Broughton Park, Manchester, 7.

Year of Election

1919 Henry Humphreys, 101, Frederick Street, Oldham
1922 Ronald Humphries, A I C , The Bungalow, 49, New-earth Road, Walkden
1923 J Wilfrid Jackson, D Sc , F G S , The Manchester Museum, The University, Manchester, 13
1943 Professor Willis Jackson Penlee, Knutsford Road, Wilmslow
1923 R W James, M A , B Sc , The University, Cape Town, South Africa
1943 Professor Geoffrey Jefferson, High Bank, Stenner Lane, Didsbury, Manchester 20
1943 Mrs Jefferson, High Bank Stenner Lane Didsbury, Manchester, 20
1942 C W Jones, M A Ellesmere House Ellesmere Park, Eccles, Manchester
1924 Francis Jones, F R I B A 178 Oxford Road, Manchester, 12
1923 P Guthlac Jones Malista, Limefield Road, Kersal, Manchester, 7
1928 Professor J Kenner D Sc , Ph D , F R S The College of Technology, Manchester, 1
1938 Jack Kerfoot, B Sc , A I C , 104, Bank Top, Blackburn
1940 C M Keyworth, M Sc (Leeds) F I C A M I Chem E , Churnet Works, Leek, Staffs
1940 P Krug, Dr Nat Science (Prague), Manchester Oxide Co Collyhurst, Manchester, 10
1931 H S Land, 24, Hillington Road, Ashton-on-Mersey, Cheshire
1909. Professor W. H. Lang, M B., C M , D.Sc , M.Sc , F R.S., F.L.S., 2, Heaton Road, Withington, Manchester, 20.
1919. J. E. Lea, B Sc., M I Mech.E., c/o Lea Recorder Co. Ltd., Recorder House, Cornbrook Park Road, Manchester, 15.
1917. Sir Kenneth Lee, LL D , Messrs Tootal Broadhurst Lee Co., Ltd., 56, Oxford Street, Manchester, 1
1940. H. R Leech, 12, Rutland Drive, Salford, 7, near Manchester.

Year of Election

1931. Miss C M Legge, M A, A R C A, The Manchester Museum, The University, Manchester, 13
1943 Miss Myce Dorothy Leigh, M A, Lyncroft, Higher Ainsworth Road Radcliffe, Manchester
1943 Miss Margaret Lever, Lyncroft, Higher Ainsworth Road, Radcliffe, Manchester
1941. W A Locan, The Firs, Talbot Road, Glossop
1938. R. D. Lord, M Sc, 635, Wilbraham Road, Chorlton-cum-Hardy, Manchester, 21
1938. A C. B. Lovell, B.Sc, Ph D, 29, Parkwood Road, Northenden
1928 H Lowery, D Sc, Ph D, M Ed, F Inst P, F.C P, Principal, South-West Essex Technical College, Forest Road, London, E 17
1936. G W Mack, B A, 30, Lonsdale Road, Manor Road, Levenshulme, Manchester, 19
1941 Rev H McLachlan, M A, D D, Summerville, Victoria Park, Manchester, 14
1943 Miss Marion V Malcolm-Hayes, Mayfield The Hough, Wilmslow
1930 Miss I Manton, B A, Sc D, Ph D, The University, Manchester, 13
1931 E N Marchant, Whetherstones, Wilbraham Road, Chorlton-cum-Hardy, Manchester, 21.
1941 A. R. Martin, 20, Styal Road, Wilmslow, Cheshire
1929. H G. Mather, Sunnymead, Hamilton Road, Whitefield.
1939. Mrs. A D. Melland, 17, Ladybarn Road, Fallowfield, Manchester, 14.
1939 C. H. Melland, M D, 17, Ladybarn Road, Fallowfield, Manchester, 14.
1927. W Melland, M.A, J.P, 1B, Cooper Street, Manchester, 2.
1920. Professor L. J. Mordell, B.A., M.Sc, F.R.S, The University, Manchester, 13.
1936. Professor John Morley, Ch.M, F.R.C.S, The Elms, Wilmslow Road, Didsbury, Manchester, 20
1941 Miss Sheila Morris, S.R.N., S C M., "Slade Mount," Slade Lane, Levenshulme, Manchester

Year of Election.

1942 E B Moullin, 77, Framingham Road, Brooklands, Cheshire

1912 J E Myers, O B E, D Sc, College of Technology, Manchester, 1

1942 Sir Christopher T Needham, Fair Oak, Palatine Road, West Didsbury, Manchester, 20

1927. J M Nuttall, D Sc, The University, Manchester, 13.

1936 T H Oliver, M D, Northern Assurance Buildings, Albert Square, Manchester, 2

1941 Miss E Owen Geographical Association, Municipal High School of Commerce, Princess Street, Manchester

1919. D M Paul, B Sc, A I C, 62, Kenwood Road, Stretford, Manchester

1942 David Pearson, B A, 22, Dryden Avenue, Cheadle, Cheshire

1928 Sir Robert H Pickard, D Sc., F.R.S, Paxford, Holly Road, Wilmslow, Cheshire

1934 Professor M Polanyi, M D, Ph D, Sandileigh Avenue, Withington, Manchester, 20

1931 Professor W J Pugh, O B E, B.A, D Sc, I G.S, Rathen House, Spath Road, Didsbury, Manchester, 20

1936. Norman Pye, B A, 10, Cavendish Road, Bath

1901. H Ramsden, M.D., M.B., Ch.B., Briarfield, Dobcross, Saddleworth, Nr. Oldham

1931. A McL Ranft, 1, Framingham Road, Brooklands, Cheshire.

1923. Professor H. S. Raper, C.B.E, D.Sc., M.B, Ch.B, M.Sc., F.R.S., The University, Manchester, 13.

1929. Dr. W. J. Sutherland Reid, Cringle, Cheadle, Cheshire.

1920. Professor A. D. Ritchie, M.A., (Life Member), The University, Manchester, 13.

1909. Miss Rona Robinson, M.Sc., F.I.C., (Life Member), Mosley Villa, Mitford Road, Fallowfield, Manchester.

Year of Election.

1943. Gregory G. Sarris, c/o Messrs. R. Street & Co., 15, Cross Street, Manchester.

1919. F. Scholefield, M.Sc., The College of Technology, Manchester, 1.

1931. J. Shirley, M.Sc., Department of Geology, The University, Sheffield, 10.

1920. W. A. Silvester, M.Sc., 4, Claremont Road, Cheadle Hulme, Cheshire.

1941. A. P. Simon, Lyndale, West Didsbury, Manchester, 20.

1915. Sir Ernest D. Simon, M.A., M.Inst.C.E., Broomcroft, Ford Lane, Didsbury, Manchester, 20.

1906. Norman Smith, D.Sc., F.C.S., The University, Manchester, 13.

1920. C. W. Soutar, M.A., B.Sc., Ph.D., 58, Kenwood Road, Edge Lane, Stretford, Manchester, 20

1926. W. M. Speight, M.Sc., The Grammar School, Manchester, 13.

1911. Miss Laura E. Start, M.Ed., Holmwood, Mayfield Road, Kersal, Manchester, 7.

1921. Harold Stevenson, F.I.C., Slievemore, 9, Westwood Road, Heald Green, Cheshire.

1933. David Stewart, D.Sc., M.R.C.S., L.R.C.P., The University, Manchester, 13.

1936. Sir John S. B. Stopford, M.D., Sc.D., F.R.S., The University, Manchester, 13.

1936. J. F. Straatman, Ir. (Delft), A.T.I., 208, Heywood Road, Prestwich, Manchester.

1924. Stephen H. Straw, M.Sc., The University, Manchester, 13.

1924. G. A. Sutherland, M.A., Dalton Hall, Victoria Park, Manchester, 14.

1938. H. Frankland Taylor (Life Member), Innisfree, Lyme Road, Disley.

Year of Election.

1937. W H Taylor, Ph.D , D Sc., 30, Broadway, Withington, Manchester, 20

1919 F H Perleski Oakwood, Hilton Lane, Prestwich, Manchester

1921 Professor F C Thompson B Sc M Sc , D Met , The University, Manchester, 13

1922. Franklin Thorp, Birchdene, Whitefield, Nr Manchester.

1942. H I Thorp, "Beechwood" Pinfold Lane, Whitefield

1938. Professor A R Todd, D Sc , Dr Phil nat , D.Phil , The University, Manchester, 13

1942 Dr L S Torrance, 2, Emma Street Waterloo Road, Cheetham, Manchester, 8

1931. F. C Toy, D Sc., Tregays, Fletsand Road, Wilmslow, Cheshire.

1936. Miss H. L. Tuer, 3, Holly Thorn Avenue, Cheadle Hulme, Cheshire

1931 H A Turner, M Sc , A I C , (Life Member), Ministry of Supply, Chemical Defence Research Station, Porton, Wilts

1921. H Walkden, The Raft, Derbyshire Road, Sale, Cheshire,

1924. C Walmsley, M.A., 6, Studley Avenue, Halifax, Nova Scotia.

1936. Professor T. B. L. Webster, M.A., (Life Member), Department of Greek, The University, Manchester, 13.

1942. Professor F. E. Weiss, Easedale, Woodway, Merrow, Guildford.

1943 Frank W Whaley, M.Sc , 126 Shaw Heath, Stockport.

1940. D. E. Wheeler, B.Sc., Ph.D., Halloween, Grove Avenue, Wilmslow.

1917. Miss Grace Wigglesworth, M.Sc., The Manchester Museum, The University, Manchester, 13.

1901. *Professor R. B. Wild, M.D., M.Sc., F.R.C.P., 180, Horninglow Street, Burton-on-Trent.

Year of Election.

1919. A. F. Williams, Seven Oaks, Bexton, Knutsford, Cheshire.

1920. J. C. Withers, Ph.D., A.I.C., The Shirley Institute, East Didsbury, Manchester. 20.

1916. J. K. Wood, D.Sc., F.I.C., 29, Altrincham Road Gatley, Cheshire.

1905. H. J. Woodall, A.R.C.Sc., (Life Member), 261, Adswood Road, Stockport.

1929. *A. H. Worthington, LL.D., Scotscroft, Didsbury, Manchester, 20.

1923. George E. Yarrow, M.Sc., A.I.C., Dayspring, 13, Lynton Park Road, Cheadle Hulme, Cheshire.

This list is in conformity with the records of the Society, but members would perform a service in notifying any changes to the Assistant Secretary.

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NOTE.

Biography of Captain Thomas Brown (1785—1862), A former Curator of the Manchester Museum

By J. WILFRID JACKSON, D.Sc., F.S.A., F.G.S.
(*Senior Assistant Keeper, Manchester Museum*).

In 1905, in a paper on the Conchological Writings of Captain Thomas Brown,[1] the late Dr. C. D. Sherborn, after giving a list with notes on the Conchological books published by Brown, concludes by remarking—" It is curious how rarely any contemporary reference is found to these books. The same remark applies to their author. Captain Brown's history is so imperfectly known that it would be difficult to string together a running story. He is not referred to in the ' Dictionary of National Biography ', and this not merely by oversight so far as the ' Supplement ' is concerned."

For many years I have been endeavouring to get together sufficient material for a biographical notice of this prolific writer, and venture to present the following as a contribution thereto. The information is gleaned from many sources, some from works by Captain Brown which I have seen, some from contemporary and later book-catalogues, and some from various friends. Among the latter I should like to mention the late Dr. C. D. Sherborn, the late B. B. Woodward, Messrs. A. S. Kennard, Alexander Reynell, J. R. le B. Tomlin, and R. Winckworth, all of whom kindly answered enquiries and supplied details. I am also indebted to Mr. D. W. May, of the Manchester University Library, who sought out books for me to consult.

Captain Brown[2] was born at Perth in 1785, and received his early education at the Edinburgh High School. In that city he also acquired some knowledge of anatomy. From early boyhood he took a keen delight in the study of natural history with the result that in later years he became proficient in many of its branches and blossomed out as an author of several popular works. Though a good all-round naturalist, his speciality in later years seemed to be in the study of recent and fossil conchology. Judging from references in his books, he seems to

[1] Sherborn, Proc. Malac Soc., VI., 1905, pp. 358-360.
[2] See Obituary in Report Manch. Field Nat. Soc., 1863, p. 12.

have travelled a great deal in search of shells or of information concerning them. Many places in Scotland are mentioned, as well as other parts. Conditions of travel would be difficult in those early times. Prior to enlisting in the army he was employed in the engraver's shop of R. Scott (father of Wm. Bell Scott), Parliament Stairs, Old Parliament House Square, Edinburgh.[1] At about 20 years of age Brown joined the Forfar and Kincardine Militia, was appointed Captain in 1811, and served in Ireland, being stationed for some time at Naas and Clonooney Barracks, King's County. His regiment was at one time stationed in Manchester, which perhaps accounts for his subsequent connection with the town. It is interesting to note that some of his early books on shells were printed in Manchester.

In 1810 he visited Northumberland where he collected some marine shells near Tynemouth with Mr. Hancock, of Newcastle, and drew others in the cabinet of Mr. Dixon, of Bishop-Wearmouth. In 1813 he collected a freshwater shell, "*Lymnaea ovata* Lam," in ditches at Bury, Lancashire. This may have been when on a visit to Mr. Thomas Norris, of Red Vales, near Bury. That Brown added shells to the latter's cabinet is gathered from a reference in one of his works to the presence in the Thomas Norris collection of a marine species, *Fusus babylonicus* Brown (a "*lusus*", like *Fusus antiquus*), found by Brown on the strand opposite Hull.[2]

In 1816, when 31 years of age, Brown published his first book, "The Elements of Conchology" (168 pp. 9 pls. col.), the figures being drawn by himself and engraved by R. Scott, of Edinburgh. This work, which was dedicated to Sir James Edward Smith, M.D., F.R.S., President of the Linnean Society, was printed by J. Gleave, of Manchester, a well-known printer of the time. According to the title-page, Brown was then a Captain in the Forfar Regt., Fellow of the Linnean Society, Member of the Wernerian Natural History Society, and Honorary Member of the Literary and Philosophical Society of Bolton. In describing the System of Nature, Brown makes the novel

[1] See "Autobiog. Notes of W. Bell Scott," vol. I. 1892, p. 45.

[2] In 1842, Thomas Norris made a valuable donation of reptiles to the museum of the Manchester Natural History Society.

statement that the young student may more easily understand the meaning of the classes, orders, etc., into which the three Kingdoms are divided, if we compare : A class to an Army ; An order to a Regiment ; A genus to a Company ; and a species to a Soldier. On page 129 hints are given on the collecting and cleaning of shells, and the practice of preserving and restoring the epidermis by the use of Florence oil is brought forward as a new idea. Hitherto, worn specimens were given a coating of gum arabic in order to restore them. In one of my two copies of this work, plates 1, 2, 3 and 4 are uncoloured ; in the other copy all the plates are coloured and plate 7 is without the names of Brown and Scott at the foot. I also possess two loose hand-coloured original plates. The original selling price of the work appears to have been 8/- plain ; 12/- coloured.[1]

During his stay in Ireland Brown appears to have found time to pursue the study of conchology and collected land and fresh-water shells from numerous localities, especially around Dublin and the above-mentioned barracks. The results of his researches were communicated to the Wernerian Natural History Society (which he joined in January, 1814) in a letter dated 20th August, 1815, written from Naas Barracks to Professor Jameson, the President, and these were published in his " Account of the Irish Testacea " in 1818 (1817),[2] illustrated by one coloured plate, the figures being drawn by himself and engraved by E. Mitchell. This work appears to be the first of any importance published on the Land and Freshwater Mollusca of Ireland, and in it Brown recorded 56 species, only 9 of which have since been deleted from the Irish list mainly on account of some doubt as to the species or locality. He had previously sent a note, in 1814, to the same Society on the Mollusca of

[1] See "The English Catalogue of Books, 1801 1836," London, 1914, p. 79, where the date is given as Jan., 1817.

[2] Mem Wern. Soc., vol. II, 1818, pp. 501-536, pl. 24 col. (Off-print 1817). Paper read 16 December, 1815. W Turton, in his "Conch. Dict." 1819, makes many references to Brown's paper, and on p. XI refers to an error in sending Captain Brown the spiral termination of *Serpula lumbricalis*, as from the Irish coast, which Brown described as *Turbo pentangularis*. In his "Conch. Insul. Brit." 1822, Turton corrects three of Brown's species described in the above 1818 paper. In Turton's "Man. L. & F.W. Shells of Brit. Isles," New Ed., by J. E. Gray, 1840, pp. 29-32, Brown's list of Irish shells is incorporated in the Table ; a few citations are given on other pages.

Ireland, but this does not appear to have been published separately from the above. In addition to being a member of the Wernerian, Brown, at that time, was also a member of the Kirwanian Society. In 1818 he published an Appendix on Mollusca to a paper by T. Allan entitled " Sketch of the Geology of the environs of Nice ".[1]

When his regiment was disbanded, Brown invested his patrimony in a flax-spinning mill in Fifeshire, but the building was burnt down, uninsured, and Brown was compelled to make a living as a scientific author. He fixed his residence in Edinburgh and there wrote and compiled many of his works on natural history, generally drawing and colouring his own illustrations and engaging Lizars, Aikman, Milne, Miller, and other celebrated men as his engravers.[2]

At 34 years of age, in the year 1819, Brown was commissioned by the Senatus Academicus of Edinburgh University to proceed to France to inspect the splendid museum of M. Dufresne, chief of the preserving department, at the Jardin des Plantes, Paris, which was then for sale, and if he approved of it, he was to purchase it on behalf of the College. The collection was duly approved and accordingly purchased by Brown. The intimacy then formed with M. Dufresne, one of the best naturalists in Europe, afforded Brown ample opportunity of becoming acquainted with all the different processes employed in the preservation of animals. He was the more anxious to acquire this knowledge that he might be of use to the Edinburgh Museum, which, by the above magnificent purchase, acquired 1,600 birds, 12,000 insects, 2,600 species of shells amounting to upwards of 5,000 individuals. There were besides upwards of 2,000 fossils, and a beautiful collection of about 800 eggs accurately named, with numerous other things, such as quadrupeds, corals, echini, etc.[3] In the same year, 1819, he was at the British Museum, where he drew Montagu's original specimen of *Patella apertura*. On that occasion he probably first became acquainted with Dr. W. E. Leach of that Institution.

[1]Trans. Royal Edinburgh Society, VIII, 1818, pp. 453-464, pls. IX, X.

[2]Scott, the engraver, worked between 1799-1824, when the house was destroyed by fire (Sherborn, in lit.).

[3]See Preface to Brown's " The Taxidermist's Manual," 20th Ed. N.D.

This is gathered from the reference in one of his books to "W. E. Leach, M.D., MS. Catalogue of British Cirripedes and Bivalves in a series of letters to Captain Thomas Brown 1820".[1] In 1821 he was a Fellow of the Royal Society of Edinburgh, and communicated a description of a worm (*Ascaris pellucidus*) found in the eyes of Indian horses.[2] This was referred to later by Férussac [3]

In 1823 Brown contributed an article on "Conchology" to the Encyclopedia Britannica.[4] This work was possibly begun by Leach and finished by Brown, who drew the plates and whose then unpublished plates of his 1827 book are cited. Printed proofs of the first 116 pages of an unpublished work by W. E. Leach, entitled "Synopsis of British Mollusca, 1820," were in circulation a year or two before, but whether Brown saw or possessed a copy is unknown. In this work, Leach describes a marine species, *Scaphander browni*, after Captain Brown, who he says "is now preparing a work on British Conchology". On a later page (in manuscript) Leach also describes *Natica browniana* to replace the *Nerita glabrissima* Brown 1818. Leach says the latter was afterwards given to Dr. Goodall. The *Scaphander browni* (considered by Jeffreys as the young of *S. lignaria*) is not mentioned by Brown in his 1827 work, nor in the "Illustrations" 2nd ed., 1837-1844, but *Nerita glabrissima* is referred to in both works (in the latter under *Natica*), no mention being made of the change of name. Leach also makes reference to three other species of Brown, 1818, viz., *Helix elliptica*, *Trochus discrepans* and *Anomia pellucida*.[5]

The year 1827 saw the publication of Brown's "Illustrations of the Conchology of Great Britain and Ireland", a quarto work illustrated by 53 coloured plates with descriptions on fly-leaves between. The figures are excellent, being drawn and coloured by Brown himself and engraved by W. H. Lizars, of

[1] See Bibliography in Brown's "Illus. Land and Fresh Water Conch B.G. and I.", 1845, p. 133.

[2] Trans. Roy. Soc. Edinb., IX., pt. I, 1821, p. 107.

[3] Férussac, "Bull. Univ. Sci. Indust.", 1824, I, p. 300.

[4] "Ency. Brit." ed. 6, VI, 1823, pp. 385-488 and 481X-483X, 4 pls.

[5] The "Synopsis" of Leach was edited by J. E. Gray and published in 1852.

Edinburgh The work, which was printed by John Stark,[1] was dedicated to His Grace Walter Francis Duke of Buccleuch and Queensberry Several new genera and species were described, including foraminifera, barnacles, etc, in addition to mollusca *Lymnaea ovata* of large size was figured from ditches at Bury, Lancashire Some copies of the work occur in which the plate numbers have been altered in ink and some of the numbers are in Arabic and others in Roman type[2] According to the title page, Brown was then a Fellow of the Royal Society of Edinburgh and of the Linnean Society Member of the Wernerian, Kirwanian and Phrenological Societies, Honorary Member of the Literary and Philosophical Societies of Bolton and Whitehaven The publication price of the work appears to have been £5 5s od A copy of the work in my possession has an original cover with title in which the word "Conchology" is larger than the others and is embellished with figures of marine shells It is worthy of note that the collection of Irish shells formed by Brown was then in the cabinet of Lady Jardine, of Jardine Hall, Dumfries Brown also cites shells from many interesting sources, such as "*Mytilus elegans* Leach MS, a new species, from the Bell Rock, Firth of Forth, discovered by my ingenious friend Robert Stevenson, Esq, Civil Engineer" (Pl XXIX), and *Chiton discrepans* Brown sent by George (error for William) Lyons, Esq, of Tenby, Wales (Pl XXXV). Shells are figured from the collection made by his late friends Captain Carmichael (sent in 1819) and John Hancock, of Newcastle (in the collection of Thomas Hancock), others from

[1]In addition to "Elements of Nat Hist' 1828 and Picture of Edinburgh, etc" (1836?) Stark published several papers on shells, fishes etc 1827-1841 He found *Dreissensia polymorpha* in the Union Canal near Edinburgh in 1834

[2]See Kennard and Woodward, Proc Malac Soc XVIII 1928, pp 36 38 The bulk of the plates must have been in existence before 1823 since they are cited by Brown in his article on "Conchology published in that year in the sixth edition of the 'Encyclopædia Britannica' A few citations from this 1827 work are made by J E Gray in 'Turton's Manual L & F W Shells of B I', 1840, W Macgillivray 'Hist Moll Anim of Aberdeen, etc 1843 (who in referring to the work, p XXI, says "No description The figures generally good, often beautiful, sometimes incorrect, the colouring bad, the nomenclature frequently strange') Charles Thorpe, in "British Marine Conchology," 1844, C Darwin, in "Cirripedia" (Ray Society), 1854, and "Mon Foss Balanidæ and Verrucidæ (Pal Soc)," 1854

the magnificent museum of John Trevelyan at Wallington, Northumberland (collected by W C Trevelyan) and the cabinets of General Bingham of Melcombe, Dr Goodall Provost of Eton College, John Nichol Lecturer on Natural Philosophy, Dr Leach, Dr Macgee of Belfast M J O Kelly of Dublin, James Gerard, of Edinburgh and Stewart Ker of Greenock

During the succeeding ten years or more Brown appears to have been very prolific in his writings many of which met with a good reception and were favourably reviewed in the Press Some were severely criticised In May, 1829 he published his "Biographical Sketches and Authentic Anecdotes of Dogs This included a historical introduction and a copious appendix on the breeding, training, diseases and medical treatment of dogs, together with a treatise on the Game Laws of Great Britain a total of 570 pages It was published by Oliver and Boyd, Edinburgh, at 8s 6d[1] This work was followed in August, 1830, by his "Biographical Sketches and Authentic Anecdotes of Horses, with a Historical Introduction, and an Appendix on the Diseases and Medical Treatment of the Horse" It was published by Lizars, of Edinburgh, at 9s[2] In 1830 he also published short notes as follows "Description of five new British Species of Shells'[3] 'Observations on Mr Kenyon's paper on British Land and Freshwater Shells",[4] "A new species of British Fish (*Platessa carnaria*)'[5] "An Account of the Whidah Bird (*Emberiza paradisea*)"[6] and "A Monograph on the Pisidium, a new genus of British Freshwater Testacea"[7]

In October, 1831, the following was advertised as on sale, "Sketches and Anecdotes of Quadrupeds" (Royal, 18mo 10s).

[1]See Engl Cat of Books 1914, p 79

[2]Ibid 1914 p 79

[3]Edinb Journ Nat & Geog Sci I (Oct 1829) 1830 pp 11 12 1 plate col, figures drawn and engraved by Brown who also drew and engraved figures on plate II of species of worm to illustrate a paper by Wm Rhind (p 29) and drew figure on plate III (engr Lizars) for Dr Kemp s paper on Electricity (p 91)

[4]Ibid I 1830, pp 65-6

[5]Ibid I, 1830 p 99, pl III (dr Brown, engr Lizars) Férussac, Bull" XXIII, 1830, p 272

[6]Ibid I, 1830, pp 341 425, pls VIII-X Isis, VI, 1832, p 583

[7]Ibid I, 1830, pp 411-413

In the same year parts began to appear of Brown's "Illustrations of the American Ornithology of Alexander Wilson and Charles Lucian Bonaparte." A notice of this appeared in December, 1830.[1] There is some difficulty in collating the parts and in ascertaining the date of its completion. In the Salford Library Catalogue, 1891, Section I, the complete work is given as 1831. Sherborn (in lit. 24—6—1918) says "parts 2, 4, 5, 6, 7, 8 and 10, all dated 1831, but some printed on 1832 paper." Part 9 was advertised as published 1833 in "The Miscellany of Natural History," vol. I.[2] Agassiz gives 1835.[3] A work by Brown, called "Ornithology, No. 1" (Imp. 4to, June, 1827, 15s.; 1 p. 18s.), is mentioned in catalogues,[4] but it is not known if this is the same work.

In August, 1832, was published the first edition of Brown's "Book of Butterflies, Sphinges, and Moths" in two volumes with 96 coloured illustrations (3s. 6d. per vol.). A second edition appeared in three volumes in 1834 with 144 coloured plates, also woodcuts. The date of this edition has been given as 1837 and the price 10s. 6d.[5] I have the second edition, three volumes, each of which bears the date 1834. The dedication is to "The Honourable Mrs. Colonel Ogilvy, of Clova, Edinburgh, July, 1832." The edition was printed by M. Aitken, 1, St. James's Square, Edinburgh, and published by Whittaker and Co., London; Waugh and Innes, Edinburgh. I have also a single volume with the title "The Book of Butterflies and Moths, etc."[6], by Captain Thomas Brown, dated London, 1843 (George Routledge). It is illustrated with 48 coloured engravings, also woodcuts. It is clearly a re-issue of volume III of the second edition, except that the set-up of the type in pages 221-222 is different, the spaces between the words and lines being wider. In this copy, as in volume III of the second

[1] Ibid. III., Dec. 1830, p. 78, as about to be published by Constable and Co.: Professor Jameson being responsible for the letterpress, and Captain Brown for the illustrations. It is there stated that Sir W. Jardine had in the press an edition of a similar work in three volumes.

[2] See also Mathews & Iredale, "The Austral Avian Record," vol. IV., March 7, 1922, pp. 176-194.

[3] Agassiz, "Bibliog. Zool. et Geol.", vol. I, 1848, p. 456.

[4] "Engl. Cat. Books," 1914, p. 79.

[5] "Brit. Cat Books," 1853.

[6] Note absence of Sphinges.

edition, is a charming "Moral for Captain Brown's Book of Butterflies, by Charles Doyne Sillery, Esq., author of 'Vallery' etc.", in verse.

Sometime in 1832 there appeared Goldsmith's "History of the Earth and Animated Nature" with an appendix by Captain Thomas Brown. A copy in the Manchester University Library (ex Manchester Museum) is entitled "Anecdotes of the Animal Kingdom . . . . . forming an Appropriate Supplement to Goldsmith's Animated Nature," by Captain Thomas Brown. It is dated, Glasgow, 1833.[1] Another copy (perhaps a later edition) with the same title as that at Manchester is in the British Museum (Natural History) and is dated, Glasgow, 1840. A further copy with the first title, "A History of the Earth, etc., . . . and an Appendix by Brown," is also in the same institution and is dated 1840.[2]

In January, 1833, Brown published "The Zoologist's Text-Book" in two volumes, one of text (issued 1832) and the other of 107 plain plates engraved by R. Scott. The text consists of Introduction (pp. I to XII) and 578 pages of descriptive matter. The work was published in Glasgow (Fullarton) at 21s. The plates are marked in Roman figures, I, etc., at the top on the right, but also have other Roman figures, prefixed by G., at the top on the left, as in "The Conchologist's Text Book" (see below). Some plates are not numbered on the right. The plates had evidently been in existence some years, as Scott's business ceased in 1824. On the title page, Brown is given as F.L.S., M.W., K.,[3] and Phrenological Societies, also President of the Royal Physical Society.

In the same month, Brown also published "The Taxidermist's Manual" (Fullarton, Glasgow, 4s. 6d.). Of this work there appeared several further editions, the 8th in 1849; the 9th in 1851; the 11th in 1853. A 20th edition of 150 pages and 6 plates is undated. He also edited an edition of "The Natural History of Selborne" by the late Rev. Gilbert White, adding copious footnotes. It was published in Edinburgh in January,

[1]The "Engl. Cat. Books," 1914, p. 79, gives "Feb. 1834" and the selling price as 10s.

[2]See Brit. Mus. (Nat. Hist.) Cat. Suppl. 1922.

[3]Member Wernerian, Kirwanian.

1833, at 3s 6d and contained 356 pages with 7 plates and text-figures This seems to have been favourably received My own copy is called " A New Edition " and the title-page bears the date 1834, though the Preface is dated January 25, 1833 It has the same number of pages, 8 woodcuts as plates, and several text figures Several editions appear to have been published by Brown, and I have seen citations of the following 4th ed , 1835 5th ed , 1835 and 8th ed , 1845 [1]

In May, 1833, Brown issued his first edition of " The Conchologist's Text-Book, embracing the arrangements of Lamarck and Linnaeus, with a Glossary of Technical Terms " It was published in Glasgow (Fullarton) at 5s and contained 180 pages of text, 19 plain plates marked in Roman figures, and some text-illustrations The work was dedicated to Sir Thomas Dick Lauder, Bart , of Fountainhall, the title page being inscribed " Edinburgh, May, 1833 ' [2] Several editions followed in later years the 3rd ed is dated 1835 , the 4th ed , 1837 , the 5th ed , 1839 , the 6th ed , 1845 (by W Macgillivray , Brown's name is omitted from the title-page) , the 7th ed (also by W Macgillivray) the 9th ed , 1870 ? (a re-issue of the 6th ed by Macgillivray) [3]

In addition to the works mentioned above, Brown published books on birds which have been subjected to much adverse criticism One of these is on " Parrots " and formed volume I of " The Miscellany of Natural History," and was written in collaboration with Sir Thomas Dick Lauder It appeared in

[1]The British Museum Catalogue 1939 gives 1836 and 1875—the latter post dates Brown's death

[2]Plates I to IX were drawn by Brown and engraved by R Scott, according to the wording at foot, and appear to be the same as those of his Elements, etc " 1816 plates X to XIX have descriptions at the foot and a few have " R Scott ' there is no mention of Brown In addition to the plate numbers in Roman, at top right, the plates are numbered G LXXII to G LXXXI at top left, as in " The Zoologist's Text Book (cited previously)

[3]A work entitled " The Conchologist's First Book " was published by Edgar Allan Poe in 1839, in Philapelphia, which is said to be an almost verbatim reprint of Brown's 1833 " Text-Book " This was denied by Poe A second edition, with a new preface, additions, and alterations, was issued by Poe in 1840, and a third, without his name on the title-page, in 1845 Poe shows early knowledge of the subject. See Allibone's " Dict Engl Lit ", vol II, 1878, p 1615, and " The Complete Poems of Edgar Allan Poe," by J H Whitty, 1917, p XLI of Memoir.

1833 and contains 36 coloured plates and 1 plain, also portrait of J J Audubon This work was severely criticised in the "Athenæum," November 30, 1833 (pp 802-4), with the imputation that the design and idea were stolen from Sir W Jardine's works 'The Naturalist's Library" On plate 19 of the work Brown figures a new species as *Psittacus swainsoni*, founded upon one erroneously identified by Swainson in his '*Zoological Illustrations*" Swainson makes no reference to this in his "Cabinet Cyclopædia, etc", 1840, in which he dismisses Brown by a curt citation to his "Elements of Conchology," 1816, saying "The figures are ill drawn and badly executed" (pp 143-4) Another advertised work on birds by Brown is "Illustrations of the Game Birds of All Countries coloured after Nature, and chiefly of the size of the originals" This is mentioned at the end of "The Miscellany of Natural History," vol I, 1833, but does not seem to have been published.

From 1835 Brown appears to have conducted "The Edinburgh Journal of Natural History and of the Physical Sciences"[1] His name as artist appears on 19 of the plates to volume I This magazine was later taken over by W Macgillivray and others From 1835 to 1840 Brown contributed an "Illustrative Glossary" to the "Historical, traditionary, and imaginative tales of the Borders and of Scotland," by John Mackay Wilson (ed) This quarto work was published in Manchester in six volumes (in three) Another of Brown's books on birds which has met with some adverse criticism is that mentioned earlier as having commenced to be issued in 1831, viz, "Illustrations of the American Ornithology, etc" It appears to have been completed in 1835[2] This work was criticised by Alfred Newton in his "Dictionary of Birds,"[3] who considered it an act of piracy on the past of Captain Brown According to a literary notice in December 1830,[4] Sir W Jardine had in the press an edition in three volumes of "Wilson's American Ornithology, with Bonaparte's continuation, etc"

[1]See review in "Mag Nat Hist", vol VIII, 1835, p 680

[2]See Agassiz, "Bibliog. Zool et Geol", vol I, 1848, p 456

[3]Newton, "Dict. of Birds," pt. IV, 1896, pp 30-31 footnote

[4]Edinb Journ Nat & Geog. Sci", vol. III, Dec 1830, p 78

In 1836, Brown contributed part of a list of land and fresh-water shells found near Edinburgh to a work published by William Rhind the Edinburgh surgeon[1] This friendship with Rhind was kept up in later years In 1837 Brown accompanied James Smith, Esq , of Jordan Hill, near Glasgow, on a dredging expedition in the latter's yacht, off Rothesay In 1839, Brown published a short paper, entitled "Descriptions and Illustrations of New Fossils," from the Pleistocene of Dalmuir, on the Clyde[2]

We now reach another chapter in Brown's life and one of no little interest In June, 1838, the post of Curator of the Museum of the Manchester Natural History Society (established in 1821), then in Peter Street, Manchester, on the site of the present Y M C A building, became vacant on the resignation of W C Williamson,[3] and Captain Brown was selected for the post, the unsuccessful candidates being Henry Mackenzie, J. Benwell, and George Crozier[4] Brown took up his duties on September 24th, 1838,[5] and continued in office until the day

[1]See W Rhind 'Excursions illustrative of the Geology and Natural History of the Environs of Edinburgh 1836 p 140 On p 121 of this work Brown's Taxidermist's Manual' is cited

[2]Mem Wern Soc vol VIII 1839, pp 104 etc plate I In earlier pages (published 1838) J Smith contributed some notes on the same Among the species described is *Bulbus smithi* Smith *Globulus smithi* Brown (now *Acrybia* H & A Adams) This fossil was found by the Duchess of Argyle who presented it to Mr Smith The original is lost J Smith published several papers about this time

[3]Williamson was appointed in July, 1835 as Curator General Manager, and Superintendent of the museum In later years he became Professor of Natural History at Owens College Thos Hewitt was Keeper of the Rooms in 1821

[4]According to Leo H Grindon, ' Manchester Walks and Wild Flowers 2nd Ed , 1859 pp 37-9, George Crozier, the father of the talented portrait painter of Manchester was a master saddler with a shop in Shudehill, Manchester a bird stuffer, and general curator at the Manchester Mechanics Institution in the late 1830's There was an excellent museum of natural history at the Institution, the chief part of which had been accumulated by the Manchester Banksian Society (established 1829) and transferred to them on the demise of the Society in 1836 George Crozier died April 16th, 1847 It is of interest to note that Thomas Townley of Blackburn botanist and painter in water colours, was the trainer of George Crozier's son Townley died September 9th, 1857 Richard Buxton, in "A Botanical Guide to the Flowering Plants, etc , of Manchester," 1849 p XI of Memoir, mentions a Thomas Townley, of Hulme, shoemaker, and a good naturalist

[5]Not 1839 as stated by Nicholson, nor 1840 as given in "Obituary," 1863

of his death on October 8th, 1862. His salary during the whole of his career was at the rate of £150 per annum. During his tenure he seems to have had continual trouble with those under him, more especially with Timothy Harrop, a man wholly ignorant of every branch of science except taxidermy. Harrop, who was appointed in the early days of the Society, in 1821, to act as " preserver," had some curious economical methods, and, on occasion, was known to give his birds one eye only if the specimens were exhibited in side view.

In the years following his appointment Brown had to view and report upon collections offered to the museum. Two such collections were minerals and fossils submitted by Mr. Mann and purchased in January, 1840 ; and the Stutchbury collection of Ammonites, etc., found in the Oxford Clay, while cutting the Great Western Railway between Chippenham and Wootton Bassett. This was in November, 1841, but I cannot find any evidence that they were purchased, though in September, 1843, fossils were submitted by Stutchbury for examination and report.[1] In addition, Brown must have found plenty of interesting work among the shells, which, apart from smaller donations, had been augmented by the purchase in 1825 of the large and important Swainson collection, which cost the Natural History Society a matter of £650.[2] Brown appears to have visited Ireland again in 1841, as he states in his " Illustrations, etc.", 2nd ed., p. 50, that he again saw the remarkable variety (the *Helix elegans* Brown, 1818) of *Helix ericitorum* Müller in the cabinet of his old and respected friend M. J. O'Kelly, of Rochestoun House, Co. Dublin, in August, 1841.

Soon after his election to the curatorship at Manchester Brown became a prominent worker for the recently established Manchester Geological Society and served on its Council, afterwards becoming the Hon. Secretary and later a Vice President. As a member of that Society he contributed, in 1841,[3] the

[1] The Manchester Museum possesses many Ammonites from the Oxford Clay which may be part of the above series.

[2] Nicholson, Mem. and Proc. Manch. Lit. and Phil. Soc., vol. 58, 1913.

[3] Trans. Manch. Geol. Soc., vol. I, 1841, pp. 63-6, pl. 6 (Paper read in 1839).

'Description of Fossil Shells found at Newtown' as an appendix to E W Binney's paper on the "Geology of Manchester and its Vicinity" The figures of the fossils were drawn by Brown and 17 new species were described, four of them being named after people with whom he had become acquainted through his connection with the two Societies Several of the so-called species have since been regarded as synonyms or young forms of others but some still stand The whereabouts of the "types" is unknown They were originally in the Binney collection Brown also drew the figures of the fish remains described by Binney in a paper entitled "On the Fossil Fishes of the Pendleton Coal Field [1] In 1841, Brown also published the "Description of some New Species of Fossil Shells found chiefly in the Vale of Todmorden, Yorkshire,' [2] again drawing the figures of some 44 forms The specimens dealt with in this paper had been industriously collected by a Hebden Bridge blacksmith of the name of Samuel Gibson Brown probably came to know of this collection through references in Phillips's "Geology of Yorkshire, vol II, 1836, this author having described certain species from that source As in the previous paper on the Newtown fossils, Brown named a number of shells after friends and acquaintances, but in the case of the cephalopoda he adopted manuscript names given by Gibson In September, 1847, the Gibson collection was offered to the Manchester Natural History Society and Brown was commissioned to inspect and report upon it The collection was bought shortly afterwards by the Society Notwithstanding the fact that the specimens bore no indication of being figured, I have been able to find quite a number of the types and these are incorporated in the present museum A few have not yet been located They may have been exchanged or donated to other institutions in the past, or perhaps lost owing to the many vicissitudes through which the collections have passed

In June, 1843, Brown published "The Elements of Fossil Conchology, according to the arrangement of Lamarck, with the newly-established genera of other authors" This was printed in Edinburgh and contained 138 pages of text and 12

[1]Ibid, vol I, 1841 pp 153-178, pl 5 (Paper read 29 October, 1940)
[2]Ibid, vol I, 1841 pp 212-229, pl 7

plain plates,[1] the figures being drawn by Brown and engraved by Milne and Aikman The work was dedicated to Edward Holme, M D, F L S President of the Manchester Natural History Society, the title-page being inscribed at the foot " Museum, Manchester, May, 1843 " It was sold at 5s[2] As mentioned later, Brown cites his " Elements of Fossil Conchology " on page 1 and later pages in his " Illustrations of Fossil Conchology of Great Britain and Ireland," showing that he was preparing the two works at the same time

In 1843 he also contributed a paper on the " Description of some new species of the genus Pachyodon,"[3] a group of Unio like shells mainly from the Coal Measures and now better known as *Carbonicola* Twenty six new species were described and figured but some of these are now regarded as synonyms of earlier species Several were named after personal friends, such as James Gerard, of East Lothian, Miss Dawson of Low Moor an accomplished geologist William Rhind, a surgeon of Edinburgh, and the author of " The Age of the Earth etc ", Thomas William Embleton, of Middleton Hall, near Leeds, Mrs William Hey of Leeds, an expert conchologist, and Miss Aldam, of Leeds an excellent conchologist

Early in 1844 Brown gave a course of natural history lectures in the museum to the Governors, Subscribers and their families, especially adapted to the young He made donations to the museum, in that and later years, of ethnographic material, birds, etc The year 1844 also saw the completion of his second edition of the " Illustrations of Recent Conchology of Great Britain and Ireland," a quarto work with 62 coloured plates[4] This was printed by Thomas Sowler, of St Ann's Square, Manchester,[5] and, like the 1827 work, was

[1]The plates are numbered in Roman figures

[2]The following citations are made in footnotes p 15 Brown's Illus Foss Conch G B & I plates 4 to 20X p 16 ditto, pl XVI, f 6

[3]Ann Mag Nat Hist, vol XII 1843 p 390 plate

[4]Often given as 59 plates but there are three extra plates marked with asterisks in copies which I have seen In some copies the plates are uncoloured, in others they are mixed, coloured and plain

[5]Thomas Sowler started the " Manchester Courier " in 1825 There seems to have been much trouble between him and J Garnett, of the " Manchester Guardian " See T Swindells' " Manchester Streets and Manchester Men," Second Series, 1907, p 224

dedicated to His Grace Walter Francis Duke of Buccleuch and Queensberry, the page having at the foot, "Edinburgh, 10th May, 1827" The selling price was £3 5s od The plates, with one exception, were drawn by Brown, the one of the slugs being partly drawn by the Rev B J Clarke, of Tuam The engraving was done by W H Lizars, John Miller and A F Aikman The edition seems to have been started in 1837,[1] but, like his other works, was probably delayed by Brown taking over the charge of the Manchester Natural History Society's museum His titles given in this work are M W S, M P S, Mem Manch Geol Soc, and late Pres Roy Physical Society

The above work was followed in 1845 by Brown's "Illustrations of the Land and Fresh Water Conchology of Great Britain and Ireland," in octavo, with 27 coloured plates Like the last, it was printed by Sowler It was dedicated to Robert Mann, Esq, Member of the Royal College of Surgeons etc, the page having at the foot, "Museum, Manchester, February, 1845" In one plate and part of another the figures (slugs) were drawn by the Rev B J Clarke, in the remainder by Brown, and the engravers were Lizars and Aikman On page 143 is advertised what is probably the same work under slightly different titles, viz, "Illustrations of the Land and Fresh Water Conchology of the British Islands," price 15s, and "Illustrations of the Land and Fresh Water Shells of Ireland," price 10s 6d, the first with 27 coloured plates, and the second with 18 coloured plates On page 144 the following are advertised for labelling and as obtainable from the Curator of the Museum,

[1]See Sherborn, op cit, p 358, also Reynell, Proc Malac Soc vol XIV 1920 p 116 Mr R Winckworth has also given some attention to the dates of this work and has come to the conclusion that the following are safe dates pp 1 20, 1837, pp 21 4, 1839, pp 25-124, 1843 and pp 125 144 also pp I-VI, 1844 I am indebted to him for this information also for calling my attention to changes in the founts of type used In one of his copies pp 1-24 were evidently set up in Edinburgh, in another the whole was set up in Manchester, as in my copy The setting of the type alters at page 14 and again at page 21 On page 50, the date August, 1841, is cited On page 54, under *Vitrina pellucida* Brown states, "I first observed this species in the cabinet of Mr Dixon, of Bishop-Wearmouth, in 1810, and drew and described it under the name of *Helix virides*, as it was of a green colour I afterwards met with the pale yellowish-white variety, in 1815, at Farbane, King's County, Ireland" References to 1810 are made on other pages.

Manchester : " A Catalogue of the Recent Conchology of Great Britain and Ireland," price One Shilling ; and " A Catalogue of the Land and Fresh Water Shells of Great Britain and Ireland," price Sixpence. On the same page reference is made to a forthcoming work, as follows : " Speedily will appear. The Elements of Conchology, illustrated by Engravings on Steel, by Lizars and Aikman, of all the Genera, Sub-Genera and Sections, with their Generic Characters fully elucidated." This would appear to be an intended new edition of the 1816 work, in which the plates were engraved by R. Scott, but nothing seems to be known of its issue.

In July, 1845, Brown also published a work of 154 pages entitled " A Dictionary of the Scottish Language." It was printed by Peter Brown, of Edinburgh, and published in London (Simpkin) and Manchester (James Ainsworth, Piccadilly). The selling price was 2s. 6d. In the same year, or in 1846, he seems to have started to issue a quarto work under the title " Illustrations of the Genera of Birds, embracing their generic characters, with sketches of their habits." There is some difficulty about the date of this.[1] Alfred Newton (1896) is very severe in his criticism of this work, stating that " Begun in 1845 in imitation of Gray's work, is discreditable to all concerned with it. It soon ceased to appear and remains incomplete. Had it been finished it would have been useless."[2]

About this time Brown appears to have been a member of the Manchester Mechanics' Institution and is mentioned as attending the annual meeting of February 25th, 1846.[3] About the year 1847 a work appeared under the title of " A Manual of Modern Farriery, embracing the cure of diseases incidental to Horses, Cattle, Sheep, Swine and Dogs . . . . . together with a Summary of the Game-Laws," by Thomas Brown, M.P.S., Member of the Royal Agricultural Society, etc., etc. It was published in London (Virtue and Co.) and consists of

[1]The "British Museum Catalogue," 1939, gives "Part I. London, 1846 [1845] : no more published." The " General Library Catalogue of University College, London," 1879, p. 336, gives it as " 10 pt. fol. London, 1845." The "British Catalogue of Books," 1853, gives "Part I. Roy. 4to Jan. 1847, 36s."

[2]A Newton, "Dictionary of Birds," pt. IV, 1896, pp. 30-31 footnote.

[3]See 22nd Annual Report of the above, 1846, p. VII.

920 pages and 18 plates[1] I am uncertain if this work can be attributed to Captain Brown, but it is to be recalled that this author dealt with the medical treatment of horses and dogs in 1830

Early in 1848 Brown was commissioned to proceed to London to select duplicate fossils at the British Museum for the Manchester Natural History Society and the Manchester Geological Society He was at that time Hon Secretary of the latter Society In the September of that year he was elected a Hereditary Governor of the Natural History Society In the December there appeared Brown's "Popular Natural History, or the Characteristics of Animals portrayed in a Series of Illustrative Anecdotes," three volumes, with hand-coloured plates It was advertised at 12s, but whether per volume or for the three is not clear[2]

In 1849 Brown completed his extensive work called "Illustrations of the Fossil Conchology of Great Britain and Ireland," which had been appearing in parts since about 1837[3] The dedication was to Charlotte-Anne Duchess of Buccleuch and Queensberry This publication, which is in quarto, has 275 pages of text, etc, and is illustrated by 117 plates engraved from drawings made by Brown[4] It is one of the most difficult

[1] Copy seen in Liverpool Reference Library not-dated, but given in the Catalogue as 1847 The same Institution contains a 31st ed Edinburgh, 1900

[2] "Brit Cat of Books," 1853

[3] According to Sherborn op cit 1905 p 359 Parts 1-8 pp 1 36 appeared in 1837, parts 9-12, pp 37-52 in 1838 parts 13-14, pp 53 60, in 1839 part 15, pp 61-64 in 1843, parts 16-20 pp 65-88, date unknown, part 21 pp 89-108, in 1843 parts 22-23, pp 109 116 in 1844 parts 24-28 pp 117-136 in 1845 parts 29-34 pp ? date unknown, and part 35, in 1849 On page 1 is cited Brown's "Elem Foss Conch" pl 11 fig 1 This was evidently not then out It was published in 1843 Page 53 setting of type slightly alters Page 74, first citation of Trans Manch Geol Soc, 1 1841 (Sherborn says this appears on page 64) Page 89, tint of paper alters Brown begins to condense references to Sowerby, I V, etc, Phillips, I, II etc Page 113 and later, fossils from Dowall, near Buxton, cited Fossils from this locality came to the museum 29 January, 1845 Pages 176 *et seq* post-1845 Page 177 tint of paper alters Pages 251 *et seq* species from Gibson collection stated to be in the Manchester Museum These came to the museum in October 1847

[4] Some copies have coloured plates in others they are plain Some of the additional plates are marked with asterisks, hence the discrepancy in the number of plates given in Book Catalogues

of Brown's works to collate and there are many imperfect copies in existence. I have seen two such copies, one in the Manchester University Library (*ex.* Bishop J. Prince Lee, 1869); the other in the Manchester Museum. The latter bears the inscription: "Presented to the Natural History Society by Emily N. Brown as a small mark of her appreciation of the kindness of the Members of the Council of that Institution and other friends, on the occasion of her Father's decease, 1862." In both copies some pages belonging to Brown's "Illus. Recent Conch," 2nd Ed., are inserted in place of the correct ones. The publication price of the complete work was £3 15s. (plain) and £5 10s. (coloured). On the title page, in addition to other Societies, Brown is given as "Corresponding Member of the British Archæological Association, and Local Secretary of the Syrio-Egyptian Society." Though neglected and looked upon as a mere compilation, this work contains amplified descriptions of fossils figured by Phillips, "Geology of Yorkshire," I, 1829; II, 1836; descriptions and figures of new species (Ammonites especially);[1] and many new appellations for species erroneously identified by various authors. New genera are also introduced in some cases. This work appears to have been the last published by Captain Brown. Probably his advanced years and the large amount of work in the Natural History Museum—far too much for one man—prevented him from continuing his writings. He did, however, get out a valuation of the collections in the museum, the details of which will be found in Nicholson's paper.[2]

In 1851 Brown prepared an elaborate scheme for the complete re-arrangement of the collections in the museum, but I do not know if this was carried out in its entirety. It was in that year that the museum received the geological collection belonging to the Manchester Geological Society, and this large influx of specimens was bound to add much to Brown's labours. This collection contained many interesting objects, including the large *Ichthyosaurus* from the Liassic rocks of Whitby, presented in 1847 by Messrs. James Heywood, F.R.S., and George Hadfield, M.P., both of whom were original

[1]See Appendix.
[2]Nicholson, op. cit., 1913.

members of the Society.[1] Other objects were slabs of sandstone showing footprints of amphibia and reptilia from the Triassic rocks of Weston, near Runcorn, Cheshire, obtained and presented to the Society in 1843 by Mr. G. S. Fereday Smith, M.A., F.G.S (also an original member) ;[2] a large collection of British fossils and minerals comprising some 4,500 specimens, obtained during a long life by Mr. Cumberland, F.G.S., of Bristol, and presented to the Society by Mr. James Heywood in 1842 ;[3] many fine Coal Measures plants collected by Mr. M. Dawes and others ,[4] also two plaster models (full size) and a set of five small models of *Stigmaria ficoides* These models were made by an Italian named Bally from fossil trees found at Dixon Fold in making the railway from Manchester to Bolton in 1837, under the direction of Mr. (later Sir) John Hawkshaw, the distinguished engineer.[5] Brown had to superintend the mounting and display of all these. In the 14th Annual Report of the Manchester Geological Society, October, 1852, he was specially thanked for his assistance in removing the geological collection to the Peter Street Museum He was then one of the Secretaries of the Society and a representative at the Council Meetings of the Manchester Natural History Society.

In 1851 also came a request from the Trustees of the Owens College for duplicates for the use of the Professor of Natural History, and Brown was ordered to make a selection of Zoological specimens for the Professor as well as one for the Salford Museum. He seems to have been kept busy in the

[1]According to the 20th Annual Report of the Manchester Geological Society, October, 1858, this specimen was restored and mounted by B Waterhouse Hawkins at a cost of £21 plus £5 5s. bonus Mr. Hawkins also provided a model showing the osseous structure and external appearance at one view He was the talented constuctor of the restorations of extinct quadrupeds at the Crystal Palace, London.

[2]Described by Dr. J. Black in Quart. Journ. Geol Soc., vol II, 1846, pp 65-68, pl V, and referred to by later workers

[3]This important collection contained several "types" of fossil Echinodermata figured by Cumberland in his "*Reliquiæ Conservatæ*", 1826, and in his MS Catalogues which came with the collection.

[4]Many have been figured.

[5]These fossil trees were described by J. Hawkshaw, in Trans Geol. Soc. Lond., 2nd ser , vol. VI, 1839, p. 173, pl. 17 ; J. E. Bowman, Trans. Manch. Geol Soc , vol I, 1841, p. 112, pls. 3 and 4 ; also by Williamson, "Monog. Stigmaria ficoides (Pal Soc.)," 1887, p. 5, pl I.

following years in attending to the requirements of the Hon. Curators; in selecting and dispatching duplicate bird-skins and fossils to other museums; and in lending specimens to other Institutions. One such loan, in 1855, was a coal fossil to Mr. J. W. Salter, of the Museum of Economic Geology, for description and illustration. A local entomologist, Samuel Carter by name, was appointed to assist Brown, but his services were later dispensed with owing to lack of funds.[1]

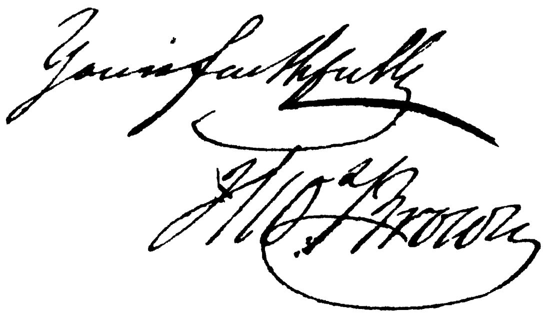
Captain Brown had many curious objects to look after at the museum. Amongst others were the mummified body of a Manchester lady, Miss Hannah Beswick; Napoleon Bonaparte's Arab-charger, "Vizier"; and the skull of a horse called "Old Billy." Other interesting objects in Brown's charge were: a column of basalt from the Giant's Causeway, North Ireland, obtained by Sir Humphry Davy, Bt., and presented by Jesse Watts Russell, Esq., of Ilam Hall, Staffordshire; and the Egyptian mummy, Asru, of the New Kingdom, together with her two body-shaped coffins, presented by Messrs. Robert and William Garnett.[2] It may have been the Egyptian mummy that led Brown to become associated with the Syrio-Egyptian Society, but I have not been able to find that he wrote anything about it, or indeed on the subject.

In later life Brown seems to have found the time and energy to join the excursions of the Manchester Field Naturalists' Society, of which he and his wife became members on its inauguration in 1860, and he was rarely absent from the Soirees. On Brown's decease in 1862, Mrs. Brown appears to have moved from Plymouth Grove to Higher Broughton, Manchester; she continued as a member of the Society until about 1867. In 1863 a bust of the late Captain Brown was presented to the Natural History Society by Mr. Kenderdine on behalf of the

[1] According to Leo H. Grindon, "Manchester Walks and Wild Flowers," 2nd ed., 1859, pp. 37-8, Samuel Carter was one of the Banksians and well known as an entomologist and the possessor of one of the largest collections of British insects in Manchester.

[2] The basalt column and the Egyptian antiquities were presented to the Manchester Natural History Society in 1825; they are now in the present Manchester Museum.

family I have so far been unable to trace this,[1] nor have I been able to discover any portrait I have a letter written by Brown to Dr Fleming on December 12th, 1840, which shows his characteristic signature It is reproduced here in the hope



that it may serve a useful purpose Captain Brown was also one of the original members of the short-lived Manchester Natural History Club which existed from 12th November, 1861, to 31st October, 1864, when it joined the Microscopical Section of the Manchester Literary and Philosophical Society Brown's successor as the Curator of the Museum was Thomas Alcock, M D a former member of the Council of the Natural History Society and Secretary of the above Club

During his lifetime, and especially when at Manchester, Brown was in touch with many celebrated men, some of whom made donations to the Natural History Society's Museum Reference has already been made to some of these people Among others may be mentioned David Dyson (1823-1856), a noted conchologist and traveller, who published an interesting little book in 1850 on "The Land and Fresh Water Shells of the Districts around Manchester"[2] Thomas Glover, of Smedley Hill, Manchester (1795-1887), a celebrated conchologist Hon. Curator of the Natural History Society in 1839 and a Vice President in 1866, donor of crustacea, mollusca, etc, to the

[1] In the British Medical Journal October 7th 1933 p 668, Dr. E Bosdin Leech gives an illustration of an unknown bust found in the Manchester Medical School but whether of a medical man or not is unknown The bust is in the classical style

[2] See my Biography in Lancashire Naturalist vol I Feb 1908, pp. 167-170

Museum in 1845; lent Brown Unios, etc., for illustration; two fossils, *Cirrus gloveri* and *Spirifer gloveri*, named after him by Brown in 1841[1]: Dr. William Fleming, of Pendleton, Founder Member of the Manchester Geological Society in 1838; Hon. Curator of the Natural History Society in 1841; donor of Indian Ocean shells to the Museum in 1844; the fossils, *Buccinum flemingi* and *Pecten flemingi*, named after him by Brown in 1841 and 1845?: Samuel Gibson, of Hebden Bridge, from whom Brown received specimens of *Anodonta cygnea* var. *subrhombea*, found by Gibson in the Irwell near Manchester; the fossil, *Buccinum gibsoni*, named after him by Brown in 1841; his fossil collection has already been mentioned: Thomas Gough (1804-1880), the surgeon, of Kendal, who supplied specimens of the freshwater pearl mussel from the River Mint, near Kendal[2]: Henry Johnson, curator of the museum of the Royal Institution, Liverpool, who supplied specimens of *Anodonta cygnea* var. *ponderosa*, from Otterspool, near Liverpool. R. D. Darbishire, of Manchester, a noted conchologist and solicitor (1826-1908)[3], who supplied specimens of *Anodonta cygnea* var. *subrhombea* from Dinting Vale, near Glossop: Viscount and Lady Combermere, of Combermere Abbey, Cheshire, who enabled Brown to secure an extensive series of *Anodonta cygnea* var. *piscinalis* while on a visit to the Abbey: Sir Oswald Mosley, Bart., F.G.S., of Rolleston Hall, Burton-on-Trent, who was Patron of the Natural History Society in 1821, and an early member of the Manchester Geological Society; he supplied Brown with varieties of the freshwater swan mussel from the lake at Rolleston.

Among other Hon. Curators of the Natural History Society to whom Brown dedicated species of fossil shells were Thomas Kirkham, of Salford (*Catillus kirkmani* Brown 1841); John Moore, of Old Sale Hall (*Modiola moorei* Brown 1841); John Samuels, of Barton House (*Avicula samuelsi* Brown 1841); John Owen, of Hollybank (*Pyramis oweni* Brown 1841, and *Avicula oweni* Brown 1845?); and Robert Mann, surgeon, of Manchester (*Buccinum manni* Brown 1841).

[1]See Obituary, Journ of Conchology, vol. V, p. 231

[2]See Biography in "Naturalist," 1894, p. 294; also J. Conch., XII, 1909, p. 310.

[3]See J. Conch, XII, 1909, pp. 258-262

In concluding this Biography of Captain Thomas Brown, attention might be called to re-issues of certain of his books some time after his death I have noted the following · In February, 1870, " Popular Natural History and Characteristics of Animals With illustrative anecdotes ", [1] in March, 1870, " Habits and Characteristics of Animals and Birds With numerous anecdotes ", [2] and " Illustrative Anecdotes of Birds, Fishes and Insects, etc "[3] In addition to these are, in 1889, " An Atlas of the Fossil Conchology of Great Britain and Ireland," ff 117, pls XCVIII, and (1919) " Illustrations of the American Ornithology of Wilson and Bonaparte "[4]

In his " Illustrations of Recent Conchology of Great Britain and Ireland," 2nd ed, pp 59 *et seq* (=post-August, 1841), Brown gives several references to shells figured and described by him in the " Popular Encyclopedia " II, p 378, pl 17 (date ?) [5] This is evidently the First Edition, 7 volumes, 1841? I have not been able to check the reference A new and revised edition of the same work, in 7 volumes, seems to have been issued in 1862 I have what appear to be two parts of this, one from vol II, the other from vol V They are undated, but on page 783 of the part from vol II, a date 1851 is quoted with reference to Eccles, Lancashire These two odd parts contain articles by Captain Brown In vol II, pp 784-5, is an article on the Echinodermata illustrated by a plate (pl XXXVI) headed " Echinodermata, Entozoa, Infusoria, Mollusca " In

[1] " Engl Cat Books " 1870, p 9 gives ' 12mo 3s 6d, J Blackwood, Feb 1870 ", " Engl Cat Books ' 1873 p 54, gives ' 3 vols, 12mo 10s 6d, 1864 ", " Brit Mus Cat ', 1939 p 639, gives " pp VI, 309, J Blackwood & Co, London [1869] 8o '

[2] Ibid, 1870 p 9 gives ' 12mo 3s 6d J Blackwood Mar 1870 ", ' Brit Mus Cat ", 1939, p 639 gives " pp VIII, 307, J Blackwood & Co, London, [1869] 8o "

[3] Ibid, 1870 p 9 gives ' 12mo 3s 6d J Blackwood, Mar 1870 ", " Brit Mus Cat " 1939, p 639, gives " pp VIII, 321, J Blackwood & Co London [1869] 8o '

[4] Both are cited in ' Brit Mus Cat ' 1939, p 638 The first is also cited by Wheelton Hind, in ' Monog Brit Carb Lamell (Pal Soc) " I, 1896, p 26

[5] Citations of this work are given in " Fossil Conchology," pp 1 and 4, as ' Pop Ency ' vol V 335, pl 65, f 1, and pl 66, f 2 These pages in " Foss Conch ' were issued in 1837 (fide Sherborn) As already stated, Scott the engraver, existed from 1799-1824 Like " The Zool Text-Book," the plates must have been in existence some years and re-used.

vol. V, pp. 619-625, is an article on the Polypi also illustrated by a plate (pl. LXXXII) headed "Polypi." The drawings on each plate are by Captain Brown, the engraver being R. Scott, Edinburgh, and the publisher, Blackie and Son, Glasgow. In the text of the part from vol. V the plate number is given as 99 instead of 82, which seems to indicate that the number on the plate was to have been altered for this edition. In a Catalogue of Second-Hand Books I have also seen references to Captain Brown, as follows: "Mollusca, ex Popular Encyclopedia, 8 p. 1 plate, containing 100 figures, 4, 1860," and "Lamarck's System of Conchology, ex Popular Encyclopedia, 8 p. 3 plates, containing 300 figures, 4, 1860."

APPENDIX.

Towards the end of 1837, the Manchester Natural History Society purchased a collection of Yorkshire fossils from W. C. Williamson, the then Curator. Among them were several of Williamson's named but undescribed forms of Ammonites. Some of these were described and figured by Brown in his " Fossil Conchology " under Williamson's names. I have found three of these, viz., *Ammonites rotifer* and *dissimilis* (two forms). These have since been described by S. S. Buckman in " Yorkshire Type Ammonites," vol. II, 1918, as *Perisphinctes rotifer* (plate 113), *Eboraciceras dissimile* (plate 118a), and *Quenstedtoceras williamsoni* (plate 118b). The *Ammonites gamma* Brown (pl. 20x) fig. 19 (not described on page 244, as stated) is another of Williamson's species. Its present whereabouts is unknown. The *Ammonites artigyrus* Brown (p. 26, pl. 19, fig. 5) is in the Manchester Museum and has been redescribed by Spath as *Androgynoceras artigyrus* (see " Cat. Ammon. Lias. Fam. Liparoceratidæ in Brit. Mus. Nat. Hist." 1938, p. 158, pl. XXIII, fig. 3 a-c). I have identified some others of Brown's types in the Manchester Museum, including *Trochus bicostatus* from the Mountain Limestone at Witherell (error for Withgill) near Clitheroe, Samuel Gibson collection (see " Fossil Conch." p. 73, pl. 33x fig. 65-7, not pl. 37x, fig. 11-13) ; this species is probably *Worthenia tabulata* (Conrad, 1835). Other types are *Petricola inflata*, from Kilsby (not Kirby) tunnel, near Coventry (p. 220, pl. 90, fig. 1-3) ; *Pholadomya compressa*, from the Great Oolite of Kettering (p. 232, pl. 95, fig. 5) ; *Axinus* (?) *latus* (pl. 79, fig. 4) ; *Axinus dubius* (pl. 79, fig. 8, ?holotype) ; *Unio humatus* (pl. 72x, fig. 18), originally described as *Pachyodon hamatus* (error for *humatus* : see Ann. Mag. Nat. Hist., Dec. 1843, p. 395, pl. 16x, fig. 6) ; *Alasmodon vetustus* (*vetustas* in error) (pl. 72x, fig. 19), originally described as *Pachyodon vetustus* (see Ann. Mag. Nat. Hist., Dec. 1843, pl. 16x, fig. 7). The two latter species are from the Jurassic (Upper Estuarine Series) of Gristhorpe, Yorkshire, and were found by Dr. Fleming. In 1911 I studied and refigured these two fossil Unios and came to the conclusion that *Unio vetustus* was the same as the earlier described *Unio distortus* of Bean (Mag. Nat. Hist. IX,

1836, p. 376, text-figure 53). I also suggested that it probably belonged to the genus *Margaritana*. In the case of *humatus*, this was left in the genus *Unio* (for details see "The Naturalist," Feb.-Mar., 1911, pp. 104-7 and 119-122, pls. IX and X).

Brown also described other new species. in his "Fossil Conchology," including *Modiola rectus* (p. 174, pl. 72x, fig. 7) and *Modiola latissima* (p. 174, pl. 71, fig. 21). These appear to me to have been founded upon Sowerby's figures, as no actual type specimens can be found. The figure of the first form agrees in dimensions and markings with the *Modiola plicata* Sowerby ("Mineral Conchology," III, pl. 248, fig. 1, right-hand side); the figure of the second form in like that of *Modiola cuneata* Sowerby, but reversed ("Mineral Conchology," III, pl 248, fig. 2 altered to *scalprum* Sowerby in the Index).

In the same work, Brown also redescribed and refigured the species dealt with by him in the Transactions of the Manchester Geological Society, vol. I, 1841. These were mainly from the lower part of the Millstone Grit Series of the Vale of Todmorden and collected by Samuel Gibson, of Hebden Bridge. It may be of interest to record here a list of the types so far discovered in the Manchester Museum with the present-day definitions.

Orthocera obtusa (Gibson MS.) Brown 1841 *Orthoceras obtusum* (emend.).

Orthocera ascicularis (Gibson MS.) Brown 1841 = *Orthoceras acicularis* (emend.).

Orthocera brownii (Gibson MS.) Brown 1841 = *Cyrtoceras browni* (Brown).

Belemnites gibsoni Brown 1841 - *Orthoceras gibsoni* (Brown).

Goniatites undulatus Brown 1841 - *Homoceras undulatum* (Brown).

Goniatites proteus (Gibson MS.) Brown 1841 - *Homoceras proteum* (Brown).

Goniatites intermedius (Gibson MS.) Brown 1841 = *Reticuloceras intermedium* (Brown).

Goniatites smithi (Gibson MS.) Brown 1841 = *Homoceras diadema* (Beyrich) var. *smithi* Brown.

Goniatites paradoxicus (Gibson MS.) Brown 1841 = *Dimorphoceras paradoxicus* (Brown).

Goniatities kenyoni (Gibson MS.) Brown 1841 = *Dimorphoceras kenyoni* (Brown).

Goniatites splendidus (Gibson MS.) Brown 1841 = *Dimorphoceras splendidum* (Brown).

Catillus minutus Brown 1841 - *Posidoniella laevis* (Brown).

Catillus kellyii Brown 1841 = *Posidoniella laevis* (Brown).

Catillus laevis Brown 1841 - *Posidoniella laevis* (Brown).

Catillus obliquatus Brown 1841 = *Posidoniella kirkmani* (Brown).

Catillus costatus Brown 1841 *Posidoniella kirkmani* (Brown).

Cytheraea antiqua Brown 1841 = ?*Schizodus antiquus* Hind.

Modiola moorei Brown 1841 = ?.

Avicula samuelsii Brown 1841 = Young of *Pterinopecten rhythmicus* Jackson ?

Gervillia minor Brown 1841 - *Posidoniella minor* (Brown).

Cirrus gloveri Brown 1841 ? *Straparollus gloveri* (Brown).

Patella greenwoodi Brown 1841 - Young of *Orbiculoidea nitida* (Phil.).

Buccinum manni Brown 1841 ? Young of *Macrocheilina elegans* (Brown).

Buccinum flemingii Brown 1841 -? *Macrocheilina flemingi* (Brown).

Pyramis reticulatus Brown 1841 -? *Rhabdospira reticulata* (Brown).

In addition to the above I have found *Goniatites parvus* (Gibson MS.) Brown 1841, and *Goniatites minutissimus* (Gibson MS.) Brown 1841.

The Nature and Function of Art.

By Rev. Canon Peter Green.

While I am very conscious of the honour done to me by an invitation to address the Manchester Literary and Philosophical Society (John Dalton's own society of which I heard when quite a small boy) yet I am also conscious that there may well be some present who are asking themselves the question: "What qualifications has Canon Green for speaking to us about Art?" Well, from one point of view I could only answer that question with the single word, "None". I am quite without executive ability in any of the arts, and even more certainly without any creative power. But I was early brought into contact with all the arts and with a good many artists of various kinds, and I have derived great pleasure all my life from many of the arts. But I have never regarded a mere accumulation of facts as in any sense real knowledge. So I felt the need of a reasoned theory of æsthetics. Such a theory should supply an answer to two questions, namely :—

(i) What is Art?

(ii) What is the place of Art among the other activities of man?

Unfortunately there is an almost complete chaos of opinion on both these points. Open at random ten books on æsthetics and you will almost certainly light on a paragraph admitting and complaining of this chaos. It is not that there are rival theories. There are no generally accepted theories at all. This may seem an extreme statement, but I will ask you to consider a few pieces of evidence of its truth.

(i) What book on æsthetics—and though the word *æsthetics* only goes back to A. G. Baumgarten (1714 to 1762), discussion, not merely about the arts but about the theory of art, goes back to Plato—has influenced men's thinking as Kant's *Critic of Pure Reason* has influenced it in philosophy, Jeremy Bentham's *Principles of Morals and Legislation* in politics, Adam Smith's *Wealth of Nations* in economics, and Darwin's *The Origin of Species* in Natural Science? I do not of course mean that every well-educated man to-day has read *The Origin of Species*, still less *An Enquiry into the Nature and Causes of the Wealth of*

Nations. But something of the teaching of the books I have named has passed into the general thinking of the race and become the heritage of all educated persons. Can the same be said of any book on æsthetics? If questioned on this point most people would, I suspect, name the works of John Ruskin, or Edmund Burke's *Philosophical Inquiry into the Origin of our Ideas of the Sublime and Beautiful*. I was, if I remember rightly, in the fifth form at school when I first came under the influence of Ruskin. But it did not last long. Once escaped from the spell of his gorgeous language it is difficult not to feel something like resentment at his wordiness, his contradictions, and his pontifical air of infallibility. As for Edmund Burke, I have long been convinced that he was incapable of anything that could be called "philosophical inquiry". Even in politics he seems to me to owe his undoubted greatness rather to noble intuition than to reason. Lessing's *Laocoön* has probably influenced more minds than any other book on æsthetics, and it is admittedly a fragment treating but one aspect of the subject.

(ii) Philosophy falls into three divisions: metaphysics, ethics, and æsthetics. And most of the great philosophers have had something to say on all three of them. But what amount of attention is paid to their writings on æsthetics compared to that paid to the first two subjects? Aristotle has certainly counted for more in æsthetics than most philosophers, and his cryptic description of tragedy as "purging" by pity and terror has become part of the furniture of the human mind. But most educated men think of him, I suspect, rather as the author of the *Ethics* and the *Politics* than of the fragment on *Poetry*. The neglect of a philosopher's æsthetic works is even more marked in the case of modern men. Edward Caird, in nearly seven hundred pages of his book *The Philosophy of Kant*, refers to *The Critic of Judgement* twice and that quite casually. William Wallace, who translated Hegel's *Logic* and his *Philosophy of Mind*, never once, in more than seven hundred pages of prologomena and preface, so much as names the *Lectures on Aesthetics*. Benedetto Croce might seem to supply an exception to what I have said. Certainly no book of his has attracted more attention than his *Aesthetic as Science of Expression and General Linguistic*, but that is probably due to his very peculiar views on æsthetics.

Had he paid less attention to the purely verbal arts and more to music and painting, I think his views could hardly have escaped considerable modification

(iii) A third point is the extraordinarily unsatisfactory character of much that has been written There are few men from whom we might have expected something helpful on the subject more than from Schiller, poet, dramatist, essavist and historian, and if not also a philosopher yet one who was interested in philosophy and lived with philosophers Yet it is difficult to imagine anything more dreary than his æsthetic writings One may read the whole series from his essay *On Grace and Dignity* to his review of Burger's poems, and if one stumbles on one striking thought it will have to do with anything except art or art theory Without going into further detail I will take one recent example from our own country The late Arthur James Balfour was a man with a well-thought-out philosophic position of his own, with the cultured man's knowledge of all the arts and with genuine musical ability But read his Romanes Lecture, *Criticism and Beauty*, and I shall be surprised if it does not produce on you the impression that here is a very clever man speaking on a subject which he feels to be important but upon which he has, unfortunately, nothing to say

(iv) But the point which I am trying to make is perhaps best established by the fact—for I am sure it is a fact—that no men are so contemptuous of æsthetic theory as artists of every kind themselves

What is the cause of the unsatisfactory state of æsthetic theory? It should not be far to seek Ethics had its beginning when Socrates insisted on the Greeks defining their terms But in æsthetics there has been no attempt to define the meaning of the words used All writers on the subject define or attempt to define art in terms of Beauty But equally all writers agree that it is impossible to define what we mean by beauty But how can anything be defined in terms of something else which is wholly undefined? We know what gold is It is one of the elements. When we speak of a gold coin, gold ore, a goldfinch or golden hair we mean in the first two cases that the thing contains some of that element, in the last two cases that they display something of the colour of gold Now make a list of a

dozen things, buildings, pictures, poems, tunes and so on, which most people would call beautiful. What have they in common? Nothing!

Let us then start altogether fresh. And first let us distinguish between Art, as a human activity, and objects of art which are the product of that activity. The distinction, often blurred in ordinary talk, is most important. Human conduct may be defined as *Conscious action directed towards a specific end.* Thus the activity of a man of science is directed to the end of right knowledge for its own sake; for though such knowledge can and probably will prove useful he desires knowledge for its own sake. The action of the moralist has for its specific end right conduct, and here, too, though honesty may in most cases be the best policy, the moral man desires right conduct for its own sake. Can we find a parallel definition for Art? Obviously we can. Oscar Wilde was right when he said that the aim of Art was *emotion for its own sake.* Most of the arts are associated with some use (architecture, furniture, pottery, etc.), or some subject (literature, the drama, poetry, pictures, etc.), but the saying: *Subject in art counts for nothing,* is none the less true. This is obvious in the greatest and purest of the arts, namely, music. Critics may amuse themselves and us by tacking on some sort of story to absolute music; as when they make the Fifth Symphony of Beethoven, the great C Minor Symphony, "Destiny knocking at the door"; but the fact remains that few people who had not heard that expression would guess it for themselves. The symphony and all absolute music gives us pure emotion divorced absolutely from ideas. Musicians often resent this either because they think we mean that it requires no intelligence to compose a great piece of music (which is absurd) or because they think, as most people do, that the realm of the emotions is in some way narrower and less noble than the realm of the intellect or of the will. Both ideas are wrong. In spite of the fact that we have a rather limited number of names for emotions, as hope, fear, love, hate, boredom, etc., the realm of the emotions is really wider than that of ideas. For emotions take their colour from the ideas we associate with them, and there can be no idea which arouses no emotion at all. The much-abused husband in "Locksley Hall", who

ranked his wife " Something better than his dog, a little dearer than his horse ", would still, even if he had valued them all equally, have felt a somewhat different emotion about each. And emotion is certainly not less noble than intellect or will since psychologists now tell us that it is emotion and not knowledge that moves to action ; a fact long known to orators. Let us then accept the definition of Art as *A human activity directed to a specific end* ; *that end being emotion recognised as desirable for its own sake.* Directly we do so we are in a position to tackle some problems which without it seem to be quite insoluble.

(*a*) *A definition of Beauty.* Beauty is not a kind of superlative of the word " pretty ". But though art cannot be defined in terms of beauty, a right definition of art supplies a right definition of beauty. An object is to be judged beautiful when it rouses in us an emotion, no matter of what kind, that is judged desirable for its own sake and not merely as a means to something else.

(*b*) *Art and Morals.* No department of our subject is more beset with pitfalls than the discussions of the relation of art to morals. On the one hand, merely didactic art is everywhere condemned. On the other hand the moralist cannot admit that there is any sphere of human conduct where the writ of the moralist does not run. When some object which its admirers hold to be of high artistic value is condemned by a magistrate on moral grounds people write indignant letters to the papers saying that the magistrate should condemn wretched books and photographs of mere pornographic character, but that he should not presume to judge works of art. But that is exactly what they are asking the magistrate to do. They are asking him to pass out of the legal sphere where he has authority and to enter that of art criticism, where he has none. The magistrate who should say : " This work is undoubtedly to be condemned as indecent, but its artistic value is so great that it cannot be condemned ", would merely make himself ridiculous.

(*c*) *Art and Education.* If indeed emotion rather than intellect does move to action the place of art in any education which aims at building citizens and not merely at stuffing children with facts should be obvious. Much of our education is, I am

sure, wasted because it is addressed to the mind and not to the emotions. I once said that few things had a more refining and civilising effect in a very rough Lads' Club than an occasional distribution of flowers. Many persons wrote to express agreement. I have found the same effect from distribution of small books of poetry or cheap but good reproductions of great pictures. The profane ugliness of many of our streets, and I fear I must say of many of our public day schools, is, I am convinced, responsible for the low standard of manners among our people. A man once asked me to use £50 in any way I liked for the benefit of Salford as a thankoffering for his fifty years of happy married life. I offered the sum to the head mistress of a municipal girls' school, suggesting that it should be spent on books for the library. She wisely spent the money on reproductions of fine pictures.

(*d*) *Art and Industry.* We are told that it is important that after the war Great Britain should greatly increase her exports. The days are over when we could sell cheap trash to the whole world. But we still have some of the finest workmen in the world, and in the past we have been specially successful in the production of fine furniture, metal work, as much old pewter work and Sheffield plate of noble design proves, fabrics and wall papers. If, after the war, we can capture a large share of the trade of the world, not with luxury goods but with utility goods of the highest quality in design and workmanship, we shall do well. The idea that machine-made goods cannot have artistic worth is absurd. The designer can still be the artist and the realm of the hand worker need not be a narrow one. But good work will never be turned out by the underpaid, overworked and discontented worker. Good work must be the result of delighted labour. Perhaps there is nowhere where a right theory of art and a due appreciation of its importance would yield more immediate benefit than in industry.

Asoka, the Philosopher Emperor.

By P. D. Mehta.

In the days when Gautama Buddha, the Enlightened One, taught in India, these words were spoken by one called Job of the land of Uz :

"Oh that my words were now written ! Oh that they were printed in a book !
That they were graven with an iron pen and lead in the rock for ever ! " (Job xix, 23, 24).

And it came to pass some fourteen generations later, that the Beloved of the Gods, one called Asoka, the son of Bindusara the son of Chandragupta, King in India, caused these words to be graven in rock :

" His Majesty King Priyadarsin in the ninth year of his reign conquered the Kalingas. One hundred and fifty thousand persons were thence carried away captive, one hundred thousand were there slain, and many times that number perished.

" Ever since the annexation of the Kalingas, His Majesty has zealously observed the Law of Righteous Living, has been devoted to that law, and has proclaimed its precepts.

" His Majesty feels remorse on account of the conquest of the Kalingas, because, during the subjugation of a previously unconquered country, slaughter, death, and taking away captive of the people necessarily occur, whereat His Majesty feels profound sorrow and regret.

" There is, however, another reason for His Majesty's feeling still more regret, inasmuch as in such a country dwell Brahmans and ascetics, men of different sects, and householders, who all practise obedience to elders, obedience to father and mother, obedience to teachers, proper treatment of friends, acquaintances, comrades, relatives, slaves and servants, and who are steadfast to their faith. To all such there befalls violence or slaughter or separation from loved ones.

" Again, even though there are persons who remain physically unhurt, yet violence is inflicted on them through their affections, for ruin falls on their friends, acquaintances, comrades and relatives.

" All this widespread misery, suffered equally by all men, is felt most deeply by His Majesty. For there is no country where Brahmans and ascetics do not exist, except among the

Yonas. There is no part of a country where there are people without faith in one or other of the sects.

" The suffering of a hundredth or even a thousandth part of the persons who were slain, led into captivity, or killed in Kalinga would now be a matter of deep regret to His Majesty.

" Although a man should do him an injury, His Majesty holds that it should be forgiven to the extent that it can be patiently borne. Even upon the forest tribes in his dominions His Majesty has compassion, and seeks to win them over to his way of life and thought. For inasmuch as the might of His Majesty lies in his repentance, so it is said unto these dwellers in the forest : ' Shun evil doing, that ye may be saved from destruction '. Indeed, for all beings doth His Majesty desire security, self-control, peace of mind and happiness.

" But the supreme conquest, in His Majesty's opinion, is the conquest of the Law of Righteous Living. And this has oft been won by His Majesty here (in his own dominion) and among all the frontier peoples even to the extent of six hundred yojanas where are the Yona king, Antiochos by name, and beyond that Antiochos, the four kings named Ptolemy, Antigonos, Magas and Alexander ; and in the south the Cholas, and the Pandyas, and as far as Tamraparni. Likewise, here in the king's dominion, and among the Yonas and Kambojas, and Nabhakas and Nabhitis, among the Pitinikas, the Andhras and the Pulindas, men everywhere follow the Law of Righteous Living as proclaimed by His Majesty. Even in those lands where there are no envoys of His Majesty, men will practise, and continue to practise the Law of Righteous Living when they hear the pious proclamation of His Majesty.

" The conquest thus won everywhere produces a feeling of happiness, the happiness of moral conquest by the devotee of the Law. Yet happiness is but a small matter ; for His Majesty thinks nothing of much importance save what concerns the next state.

" And for this purpose has this pious edict been written, to wit, that sons and grandsons, as many as they may be, should not seek to make a new conquest by arms. And should such conquest be effected, may they find happiness in patience and forgiveness. And may they remember always that the supreme

conquest is won by fulfilling the Law of Righteous Living, the Law which avails both for this world and the next state And may their happiness lie in the renunciation of all aims other than the aim of Righteous Living which avails both for this world and the next state"

So runs the Thirteenth Rock Edict

Who was this man who caused these words to be graven in the rock, and what was the fount of his inspiration?

* * * *

India in the early third millennium B C boasted several fair cities in the Indus valley It is thought that the builders of this civilisation, parallel with those of Sumeria or Egypt, were Armenoid-Mediterranean peoples, who during that third millennium B C were flooded by an immigration from the Iranian plateau and the Pamirs Meanwhile men elsewhere, in the Asian steppes and in Mesopotamia, had learned to use the horse, and in the second millennium B.C. the Indo-Aryan barbarians from the steppes of Turkestan poured over the Hindu Kush into the fertile prosperous Indus valley. They were warrior horsemen armed with swords, attacking in one wild onrush with loud cries Disciplined military tactics were unknown to them They brought their own women, and their cattle, with them, and successfully overran the pre-existing civilisation Their great gift to India was to be their language, offering a remarkable scope for mental and cultural development

The inhabitants of pre-Aryan India appear to have had their own social organisation and a developed religious system Theirs was an already ancient culture, on which came the impact of the warlike Aryans of the second millennium B C, bringing with them a religious practice based on nature gods —sky, wind, thunder, etc The invaders, though they retained their pride of ancestry and military prowess, were overawed in a religious sense by the culture of the conquered peoples Their own gods sank to a lower level than those of ancient India, among whom Siva is still the most important The priests of Siva and the Indian pantheon eventually became an exclusive Brahman caste some centuries before the advent of the Buddha. They became the ritual leaders in contrast with the administrators and warriors who constituted the Kshattriya caste.

In the Punjab the lordship of the Kshattriyas was beyond dispute; much of it was grassland on which their herds could live. But in the Ganges basin east of what is now Allahabad they penetrated only in small groups, founding lordships. They tried to keep themselves from officially recognised intermixture with the people of the land and to marry with the sons and daughters of other lords like themselves.

Like the Roman priests of the Dark Ages in Western Europe, the Brahmans sought the friendship of the Kshattriyas; and, while recognising merchants and others as to some extent privileged, as Vaisyas, both despised the common people of the conquered races as Sudras. Thus we have, broadly, the fourfold division of Hindu Society. But the earlier, simple social organisation lost its elasticity and became a more rigid and increasingly complex caste system—i.e a system in which the main object of each group of persons was to preserve in its original form or purity what was accepted as right and proper in religious worship and customs, in social behaviour and customs, in professional duties or occupations, and in the routine of physical life. Caste is derived from "castus", pure; and the term caste system was first loosely used by the Portuguese to describe the social organisation of the peoples of India.

There is evidence from the Atharva Veda (III, 4), the Aitareya Brahmana (I, 14), the Taittirya Brahmana (I, 5 and 9), the Ambattha Suttanta of the Buddhists (I, 113), the Arthasastra of Kautalya (I, 13), and the Mahabharata (Rajadharma Parva, Chapter 67), that several if not all of the earliest Aryan states may have had a republican pattern of government. Elective chieftainship was in vogue. The chief, chosen from among the best warriors, enjoyed kingly estate; but the people wielded the right to expel him, and subsequently to recall him if they so desired. This system proving cumbersome and insufficiently effective for the maintenance of security, it gave way to the establishment of an institution of select ladies on the eldest of whom it was the duty of the chief priest to beget a prince. This prince had to live a celibate life and rule the state in accordance with the will of the people's assembly. But soon these princes were fighting for the right to marry and to found dynasties. In some states the priests gave in and saved their

other privileges, while other states experienced civil war, which ended disastrously for the priests We have hints of this in the Rigveda (X, 124, 8, X, 174), and in the Atharvaveda (VI, 87 and 88), the dependence of the sovereign's power on the faithfulness of the assembly is emphasised

But when a millennium had swung past, there existed in Aryavarta great kingdoms with hereditary monarchs whose autocracy was controlled by a select inner Cabinet and by a slightly larger body consisting of the principal Ministers of State, and the powers of these governments, though they could not be constitutionally checked, were effectively limited, often enough, by a vast self-governing democratic society below. Local government in a real sense has been a vital characteristic of living India through millennia

Such, in brief was the political and social background offered in that first Aryan millennium by the great kingdoms which had developed all over Northern India to those thinkers who ascended the peaks of Transcendental philosophy and left us the legacy of the Upanishads and of the Samkhya philosophy It was an age of intellectual glory Yet it is significant that these profound thinkers first left their everyday world and retreated into forest hermitages before they made their solitary ascent Despite their high level of civilisation, all was not well in those great kingdoms And when that age culminated in the spiritual splendour of the enlightenment of Gautama Buddha, the supreme fact which impressed the keenest observer of his age was the overwhelming ubiquity of suffering in man's life The Enlightened One ministered unto his fellow men, and his teaching has moulded the destiny of man more profoundly than man cares to admit

The story of Siddhartha Gautama tells us he was a prince who for twenty-nine years was well guarded from the knowledge of pain, grief, sickness and death, and who, through his royal father's especial care, was steeped in every conceivable earthly happiness But the inevitable happened Siddhartha saw pain, grief, sickness and death Seized with the overmastering passion to solve the problem of human sorrow, he made the Great Renunciation—of his wife and child whom he loved so well, his princely estate, his worldly happiness—and wandered far

and wide, seeking wisdom. Dissatisfied with what the sages of his day had to teach him, he at last looked within himself. Enlightenment dawned on him. With it came that mental serenity, that ineffable peace which he called Nirvana. He wondered for some days whether the wisdom he had won could or could not be given to men and women. Compassion triumphed, and the Buddha taught thereafter for five and forty years all who came to him.

On individual effort and individual realisation he laid THE emphasis, rejecting the authority of the priesthood, and the efficacy of ceremonies for individual salvation. He denounced the cruel limitations imposed by the formal observance of some caste rules. He pointed out that whatsoever emphasised the distinctions between one man and another merely increased egoism, and destroyed the growth of true individuality. The desire for asserting this ego, the illusory " I am ", the fleeting external garb mistaken for the true self, was the root cause of suffering, said the Buddha. As long as man made the mistake of regarding this ever-changing illusory manifestation compounded of matter, sense and mind as the stable, permanent reality, an unchanging " I am ", all his desires would be ego-centred, would conflict with the desires of some of those around him and inevitably beget sorrow. Such a man would always be the slave of the childish " I wish , I like ; I want ", always at the mercy of his appetites and urges. All desire which was unexamined, undisciplined, unfaithful to the truth of life was the source of sorrow ; and the cessation of such desire meant the extinction of sorrow and the beginning of true happiness through pure action. For this, it was necessary to look within.

Self-knowledge, self-discipline and self-control were the keynotes for attaining freedom from all those desires emanating from the ego-centred man. Such freedom meant intellectual and spiritual maturity, the liberation of true individuality. The true individual was fully aware of his interdependence with his environment—he was " in tune with the Infinite ". He alone was wholly human, he alone capable of real love, of pure action, of true practicality. His was wisdom, the pure distillate of experience and knowledge, as contrasted with the burden of mere learning. And the sole dynamic of his whole

life was the will as well as the ability to co-operate with " the power that moves all things to good ", to use the Buddha's own words.

The true individual could enjoy the bliss of Nirvana as his normal state of consciousness. Only the ignorant or the deluded identify Nirvana with annihilation or with nothingness ; or again with happiness or rapture as we ordinarily know it or " heaven " as we understand it. We must never forget that the term Nirvana applies to a state of consciousness only. We never " go to Nirvana ". We attain that consciousness here and now– in the eternal now –a state of consciousness wherein the mind maintains absolute serenity while the individual is fully sensitive and fully responsive to the whole of his experience in the immediate present. Here only can man know what pure action, implying his freedom from mere reaction to any stimulus, means. And pure action, in wholeness, maintaining that mental serenity which spells the individual's sovereignty over self and not-self, over " I " and " my environment ", spells Nirvana. He who has freed himself from ego-centredness can understand this, for he can experience Nirvana for himelf.

The Buddha's doctrine of moral and mental development, and of the liberation of true individuality, is one of constant and strenuous endeavour in the here and the now. It is in truth an action philosophy to the profoundest degree, the very antithesis to an escapist philosophy. To look within and face the self is a far more difficult task, and needs far greater courage, patience, steadfastness, endurance and wisdom than facing external life. For the oceans of the everyday world are well charted, whereas the realm of the self is an unknown land which can be explored only in utter loneliness. But it is there that the pearl of wisdom may be found, and the finder wins the prize of Nirvana, man's eternal quest.

In his all-embracing wisdom the Buddha saw the need of adapting his teaching to suit the capacity for understanding of his people. So he discoursed on the cause of sorrow and on the extinction of sorrow. And he taught the Noble Eightfold Path and how to tread the Middle Way. And he taught something else besides. He proclaimed the universal brotherhood

of man, and to fulfil this in practice, he enunciated the principles and taught the methods of democracy. In his Samgha, the meeting was controlled by a specially appointed officer; where necessary a quorum was secured by another appointed officer; the business of the day was introduced in the form of a motion by the proposer, discussed, and the majority vote taken by ballot decided the discussion. Every member was free to speak and entitled to vote. Buddha was the first great democrat of our race. He exhorted all the peoples to rise to this level. And for more than a thousand years the benign influence of the Buddha's deep wisdom creatively stimulated Hindustan and gave birth to her two most glorious epochs.

But Buddha knew that no true democracy could be brought into being and be maintained except by true democrats. And only true individuals could be democrats, for only true individuals could be truly self-controlled, truly self-responsible, and wisely co-operative, essentials of democracy in action. Hence the moral and religious doctrine of the Buddha for individual salvation is inextricably interwoven into the fabric of a stable, harmonious and creatively active social and political order. Siddhartha Gautama, who climbed the peaks of Buddhahood and was at home in the transcendental consciousness of Nirvana, was also a human son wholly worthy of his royal father.

Some centuries before the Buddha, the sages who left us the legacy of the Upanishads had shown their discontent with the ritualism of the old Indo-Aryans and their predecessors in India as embodied in the Brahmanas and Aranyakas, great explanatory commentaries of the older Vedas. The ancient magico-religious fertility rituals were failing to satisfy thinkers who rose partly out of an aristocratic leisured class, one of the products of the gradual settling down of warrior tribes who had established dominion over vast kingdoms. The teaching of Gautama Buddha was the culmination of the growing concepts of universality and brotherhood, of the necessity of moral discipline and of the paramountcy of Reason, of the unique nature and value of individuality, and of toleration as a guiding principle of human conduct. The age in which this greatest of Hindu reformers flourished was one of rare philosophic splendour—the age of Xenophanes and Parmenides in

Elea, of Lao-tze and Confucius in China, of Mahavira in India, of Isaiah in Judah

During the lifetime of the Buddha his friend Bimbisara, fifth king of the Sisunaga dynasty, ascended the throne of Magadha in 543 B C The last of the Sisunagas married a Sudra woman and founded a Sudra dynasty of the Nandas Dhanananda was on the throne of Magadha in 326 B C when the Macedonian phalanx refused to cross the Beas and Alexander turned back towards the Indus The commander-in-chief of the Magadha army was a young man one Chandragupta who possibly had previous experience of war against the invincible Alexander

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The Greek records of Alexander's time show India to be a land of several warring kingdoms But after 325 B C Chandragupta, commander in chief in Magadha conceived of the idea of an Indian Empire, of a political unity to be forged by conquest of arms Assisted by his able statesman-financier Kautalya, he stamped out all opposition ruthlessly ascended the throne at the capital, Pathputra (modern Patna), and established the Maurya dynasty State after state fell before his military prowess and the cunning diplomacy of Kautalya By 305 B C he was master of the highlands above Herat and up to the Hindu Kush Sind, Kathiawar, Gujrat and Malwa the provinces of the west also fell under his sway and Chandragupta Maurya was suzerain over the first empire of India In the brief space of hardly a score of years, he realised imperial sovereignty over all India from Afghanistan to Assam from the Himalayas to the Vindhyas A few years later the Emperor relinquished his throne and retired to the hermitage of a Jain Saint called Bhadrabahu, dying there in 297 B C Little did he know that the child Asoka, the grandson whom he is likely to have fondled on his knees when relaxing from the burdens of state, was destined to write the most wonderful page of Indian history

Bindusara, who succeeded his father, ruled for nearly a quarter of a century Of him we know little except that he expanded the empire, consolidated it, and fixed its administration on a firm footing About 286 B C he sent Asoka, then eighteen years of age, as Viceroy to Ujjain, and later on, it is reported, to

Taxila to quell a rebellion against the maladministration of his elder brother Prince Susima, the Crown Prince. On Bindusara's death, Asoka seized the throne of Patliputra, the Crown Prince being killed (Divyavadana, Chapter 26), and four years after his accession he was crowned, in 270 B.C.

Asoka, fortunately for himself, inherited a well-organised empire. In extent, it was larger than all modern India, for, though it did not include a small region, about the size of England, in the extreme south, it included all Afghanistan and Baluchistan, and the easternmost strip of modern Iran. It was nearly two million square miles in area, yet so well organised that the royal commands issued from Patliputra were readily obeyed on the shores of the Arabian Sea and of the Bay of Bengal. Asoka's Inner Cabinet of Four consisted of the Diwan or prime minister, the Purohita or religious adviser, the Senapati or commander-in-chief, and the Yuvraja or heir-apparent. Under these, the Principal Ministers of State included the Treasurer; the Minister of Works (whose responsibilities ranged from the maintenance of public buildings to the rain gauge); the head of the Judiciary; the Minister of Correspondence, who issued the royal decrees; the Court Chamberlain; and the Commander of the Body-Guard. (B. Prasad, *Theory of Government in Ancient India*, p. 124.)

"Agriculture was the outstanding industry of the land. The practical unit of administration was the village, under its headman (gramani) an official nominee, who dealt with the revenue and supervised farming, advised by the village council of elders (panchayat). The government's policy was to provide for the even distribution of the agrarian population by systematic plantation of villages in thinly-occupied tracts. For the general improvement of agriculture officials were employed by the government 'to superintend the rivers, measure the land as is done in Egypt, and inspect the sluices by which water is let out from the main canals into their branches so that everyone may have an equal supply of it' (Strabo, quoting Megasthenes). But the government water rate, varying from one-third to one-fifth of the produce of the land, was a heavy burden. (Kautalya's *Arthasastra*, Bk. 2, Chapter 24.)

" A Gopa was the head of a dozen villages. Over several Gopas came higher officials ; and Asoka appointed Rajukas who were responsible for hundreds of thousands of people.

" The district officials, who formed the first of three categories of government servants mentioned by Megasthenes, were responsible for irrigation and land measurements, hunting, agriculture, woods and forests, metal-foundries and mines, roads and the distance stones maintained on them.

" Chandragupta had organised the management of his capital in six boards of five persons each, and these town officials formed the second category of government servants. The respective functions of the boards were :

1. Supervision of factories.
2. Care of foreigners (control of the inns, charge of the sick and the burial of the dead).
3. Births and deaths, for purposes of taxation and record.
4. Trade and commerce, supervising weights and measures and generally controlling the markets.
5. Inspection of manufactured articles and provision of distinction between new and second-hand goods.
6. Collection of the 10 per cent. tax on sales.

" The six municipal boards formed a general council to superintend temples, public works, harbours and prices, and in both town and country there were officials who kept complete registers both of property and the population. (Kautalya, Bk. 2, Chapter 36.) The superintendent of passports issued these on payment for the use of all persons entering or leaving the country. (Kautalya, Bk. 2, Chapter 34.)

" The organisation of the government machine was wonderful, but no scale of punishments could check corruption. Kautalya observes : ' Just as with fish moving under water it cannot possibly be determined whether they are drinking water or not, so it is impossible to detect government servants employed on official duties when helping themselves to money '. (Bk. 2, Chap. 9.) The third category of officials constituted the War

Office. This department also consisted of six boards of five, each being provided with a large secretariat :

(1) Admiralty	(4) Cavalry.
(2) Quartermaster-General.	(5) Chariots.
(3) Infantry.	(6) Elephants."

(Sir George Dunbar, *History of India*, pp. 38–46.)

From Alexander's local domination, conquerors of India, foreign or native, have not actually displaced the rulers they subdued. In all likelihood, the Mauryas loosely imposed their central government upon the tribal system and self-contained village communities of the land. Asoka himself ruled his empire, a confederation of States, through his four Viceroys at Taxila, Ujjain, Tosali and Suvarnagari. The independent feudalism and oligarchy of various rival states were here replaced by the highly organised bureaucracy of one paramount power supported by a huge standing army—9,000 elephants, great strength in chariots, 30,000 cavalry, and 600,000 infantry—and buttressed by swarms of secret agents and informers of both sexes.

Over this whole government machine was the sovereign. Kautalya's enunciation of the principles of foreign policy and the daily time table of the sovereign make the counsels of Machiavelli on statecraft and of Stockmar on royal duties appear almost feeble.

The capital, Patliputra, was organised in four districts, subdivided into wards and controlled by regulations ranging from precautions against fire to the official report on lost property.

What was the position of women in the Mauryan Empire? Both the regular and irregular recognised forms of marriage could be dissolved by mutual consent, or, automatically, by prolonged desertion. A married women owned her dowry and personal adornments as her own private property, which was at her own disposal to a certain extent if she became a widow. Cruelty by either husband or wife was punishable. The honour of women was carefully guarded from the point of view of motherhood. The abduction, hurt or outrage of even a prostitute, her mother or daughter or maidservant was severely punished, and in general, offences against women were dealt with severely. The time was still to come when foreign invasion was to force

Hindu Society in self-defence to follow the custom of purdah. The main disability from which women suffered in Mauryan times was that the usual age of marriage had come down to as low as thirteen or twelve. This also meant curtailment of girls' education, and also a virtual absence of the free choice of a husband. This was a sad contrast to Vedic times, when girls had as good an education as boys—universal education appears to have been prevalent then—and freely chose their own husbands, marrying usually at about seventeen or eighteen, and did not consider it a disgrace to spend a life of spinsterhood !

In the Code of Manu, Bk. III, 55 and 57, we read :—

55. Honour to the faithful woman
    Be by loving husband paid,
  By her father, by her brother,
    If they seek their virtue's meed.

57. And where women grieve and languish
    Perish men of fated race,
  But in homes where they are honoured
    Prosper men in worth and grace.

Taxation was very heavy and ingeniously comprehensive. But the cost of the elaborate system of government and of the maintenance of a highly-trained formidable standing army was also enormous. Moreover, no such expedients as national debts or long term government loans were in vogue then. Apart from the exactions of tax-collectors, the life of the peoples was quiet and fairly happy. The emperor and his court lived a life of magnificence and splendour. Hunting and gladiatorial shows, and long pleasure tours with a splendid retinue were the royal amusements. Wine, women and song all played their respectable parts in the lives of the three great Mauryan Emperors—respectable because moderate, as proved by the fact that their abilities as administrators and as generals suffered no impairment.

In an empire stretching from Afghanistan to Mysore, news from either extremity would probably take six months to reach the government centred at Patliputra. The imperial authority over this mighty sub-continent, and the system of administration, were efficiently maintained. This is a sober historical fact of a period when the means of transport and communication

were incredibly slow by modern standards. What was the secret of success? Mainly this: India of the Mauryan age was not a land of impenetrable jungles, but well developed agriculturally, with numerous arts and crafts, a brisk trade, convenient roads and trade routes, and highly industrious. Combined with these physical conditions was the administrative wisdom of the Mauryas. Their system of government gave effect to an extensive decentralisation, and to the utmost latitude to the operations of local government. Innumerable autonomous centres coped with the requirements of their own districts. This highly successful machinery of government was not an innovation by Chandragupta but a legacy from ancient times. Asoka clearly distinguishes his innovations from his inheritances. (See Rock Edict, III, VI, VIII, K.R.E II, P.E. IV and V.) When we realise the correct significance of this, we obtain a just estimate of the extent to which the autocracy of the monarch was balanced by the democracy of the people. And the loveliest element of this relationship between monarch and people is that, in general, the social and economic life of the masses, the humanness of the existence of the populace, was untouched by the wars of neighbouring kings, the setting up and pulling down of dynasties, and the rise and fall of empires.

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So we can visualise Asoka Maurya, in the beginning of his reign, ruling strictly and well, living a life as befitted a secular monarch. He was a man, a reasonably good man, in his thirties, with a family. He was an emperor, a powerful and great emperor, ruling over a subcontinent. The Hindustan of his day was the Great Power of his day. As an emperor alone, posterity could have accorded him an honoured place among the great. But spiritual grace was to descend on him and lift him to the sublime height of a successful Philosopher Emperor, hardly equalled in the annals of history, if we take into account not only the magnitude but also the quality of his achievement. First, however, he had to pass through the portal of sorrow. And this is how it happened. Five years after his coronation he was converted to Buddhism as a lay disciple. There followed about two and a half years of indifferent devotion to the new faith. It was now about 262 B.C., some twelve years since he first

ascended the throne. And then came war ; to extend his kingdom, it is said. Bloody was the battle fought by the Kalingas with desperate valour in defence of their freedom. The military might of the emperor triumphed. There could never have been any doubt of that issue. But none dreamed of the moral transformation that would take place in the strict, able, pre-eminently successful imperial monarch, at the age of forty-two, in his full maturity, at the zenith of power, least likely to be swayed by sentimentality or other weakness. And yet this was the man who was so smitten to the depths on seeing the suffering of his fellow men, his human brethren, that he abjured war as an instrument of imperial policy He espoused the cause of human security, happiness and well-being, not only for the peoples of his own vast domains but for all the peoples he could reach. He devoted himself strenuously to the Law of Righteous Living, to the fulfilment of the teachings of the Lord of Wisdom and Compassion. He neglected none of his kingly duties Indeed, he applied himself more strenuously than ever for their better fulfilment. He organised his mighty empire with its vast resources for the practical realisation of these ideals. Let us illustrate his story from his autobiography, inscribed on rock and pillar. And let us note at the outset that with the characteristic humility and simplicity of the truly great, he calls himself king only, not emperor ; to characterise his devotion he calls himself " favoured by the gods " ; and to express his genuine affection for all human beings he speaks of himself as " one who regards all with kindness ". Asoka, therefore, styles himself : " Devanampiye Priyadarsin Raja ".

In the second Kalinga Edict he emphasises the paternal principle of government : " All men are my children ; and, just as I desire for my children that they may enjoy every kind of prosperity and happiness . . . so also do I desire the same for all men ". He wants the newly-subdued Kalingas " to grasp the truth that ' the king is to us as a father ; he loves us even as he loves himself ; we are to the king even as his children ' ". Asoka goes further, and wants his agents to feel a similar personal relationship towards their people. Pillar Edict IV says : " As a man would make over his child to a skilful nurse and, feeling confident, says to himself, ' the skilful nurse is eager to care for

the child', even so my Governors have been created for the welfare and happiness of the country".

Rock Edict VI says: "A long period has elapsed during which in the past administrative business or information was not attended to at all hours. So by me the arrangement has been made that at all times, when I am eating, or in the harem, or in the bedroom, or in my ranches, or even in the place of religious instruction, or in my pleasure-grounds, everywhere the reporting officials should make known to me the people's affairs. In all places I shall attend to public business". What untiring energy Asoka must have possessed! What emphasis on a king's obligations to his people! What a conception of imperial responsibilities and duties, and an ideal of public service! Hear, further, what he declares in the same edict: "I never feel satisfaction in my exertions and dispatch of business. For work I must for the welfare of all the folk; and of that, again, the root is energy and the dispatch of business; for nothing is more essential than the welfare of all the folk".

The religious teaching of Brahmanism insisted on the discharge of three debts owed by man; to religion; to learning; and to the ancestors (by perpetuating the race). Asoka added a fourth: "And whatsoever efforts I make, they are made that I may obtain release from my debt to my fellow human beings". (R.E. IV.)

To his Governors, when neglectful of duty or indifferent to his injunctions, he addresses a vigorous and dignified protest: "With certain natural dispositions success (in administration) is impossible, to wit, envy, lack of sustained efforts, harshness, haste, want of application, indolence and lassitude. You must desire that such dispositions be not yours. At the root of the whole matter lie steadiness, and patience. He who is tired in administration will not rise up;' but one must needs move, advance, go on. There will be special officers to remind you of your obligations to the king and of his instructions. Fulfilment of these bears great fruit, non-fulfilment brings great calamity. By those who fail, neither heaven nor royal favour can be won. By fulfilling my instructions, you will gain heaven and also pay your debt to me". (K.E. I.)

He sums up the policy of his empire in a single sentence in the Thirteenth Rock Edict "The supreme conquest, in His Majesty's opinion, is the conquest of the Law of Righteous Living" Asoka believes in, preaches, and fulfils in practice the ideal of Right served by Might To the limits of his vast empire, and beyond to Egypt and Greece, went the king's message of freedom, of peace on earth and good will to man The war drum was silenced instead, the clarion call to a nobler life was heard by all For five and twenty years India enjoyed a brotherhood of nations a golden age of peace and freedom

And for the personal comfort and cheer and health of the people, and also as a free gift for neighbouring states outside the empire the Second Rock Edict says Everywhere within the dominion of His Majesty the King, likewise among the frontier peoples such as the Cholas, Pandyas, the Satiyaputras the Keralaputras, what is known as Tamrapaini, the Greek king Antiochos everywhere have been instituted by His Gracious Majesty two kinds of medical treatment—medical treatment of man and medical treatment of beast Medicinal herbs also, those wholesome for man and wholesome for beast, have been caused to be imported and to be planted everywhere wherever they did not exist On the roads, wells also have been caused to be dug and trees caused to be planted for the enjoyment of man and beast"

Asoka well understood that the greatness of an empire as well as his people's happiness rested upon the basis of individual character, and that the root of character was moral development The royal devotee and member of the Buddha's great order of monks preached morality and the rules of practical religion with a zeal and piety singularly free from bigotry and sanctimoniousness Simplicity, toleration, universal applicability, sound psychology, common sense and the clean flame of truth characterise his moral precepts for his peoples

Says the Third Rock Edict "Commendable is the service of father and mother, commendable is liberality to friends, acquaintances, relatives, Brahmans and Sramanas, commendable is abstention from the slaughter of living creatures, commendable also is it not to spend or hoard too much' And

the Fourth Rock Edict : "This is the highest work, viz., preaching of the Law of Righteous Living". And the Fifth : "The good deed is difficult of performance. He who is the first performer of a good deed achieves something difficult of performance. . . . Sin must be trodden down".

Here is the Tenth Rock Edict : "His Gracious Majesty the King does not regard glory or fame as bringing much gain, except that whatever fame or glory he desires it would be only for this, that the people might in the present and in the future practise obedience to the Law and conform to the observances of the Law. And what little His Majesty exerts himself is in order that all may be free from bondage. And this is bondage, viz., sin. This is indeed difficult of achievement by the lowly or high in rank, except by strenuous.preliminary effort, renouncing all. But among these two, it is the more difficult of achievement by the person of superior rank".

The whole of the Twelfth Edict, too long to quote here, preaches complete religious toleration. And it must be remembered that for twenty-five centuries Brahmanism, Buddhism, and Jainism, with their various sects, and a multitude of philosophies, flourished side by side.

Of the Seven Pillar Edicts here is an extract from the First : "Both this world and the next are difficult of fulfilment except by utmost love of the Law of Righteous Living, utmost self-examination, utmost obedience, utmost dread (of sin) and utmost enthusiasm". And the second : "Good is the Law. It includes freedom from self-indulgence, abundance of good deeds, kindness, liberality, truthfulness and purity".

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It is the Thirteenth Rock Edict, quoted in full in the beginning, which expresses the majesty of soul of this man Asoka more than any other of his inscriptions. We shall understand the secret of Asoka's greatness if we take it in conjunction with the following extract from the First Minor Edict : "For more than two years and a half that I had been a lay disciple, I had not exerted myself well. But a year—indeed for more than a year that I visited the Samgha, I exerted myself greatly".

" I exerted myself greatly " says the king. Exerted himself in what ? In following the teachings of the Enlightened One, Gautama Buddha.

It was the life and teaching of the Buddha which inspired Asoka the Great to become Asoka the Righteous. In that crucial period of more than a year, during his physical and intellectual maturity, he exerted himself greatly. The king of the mightiest empire of his day was likely to choose his words carefully. He uses the word " greatly ". We can imagine with what seriousness and assiduity he must have striven. And we must applaud the common sense with which he dealt with the masses. The masses need a king, and a queen. Never was Asoka without a queen, the indispensable complement to the king. The masses could not rise to the heights of Nirvana ; yet they need some transcendental symbol to draw the best out of them. So Asoka instituted religious processions which gladdened the people's hearts and made them feel nearer the gods. The masses could never go through strenuous physical, mental and spiritual training and development, as the wholehearted devotee did. So Asoka exhorted them ceaselessly both by precept and by his own superb example to live up to their highest vision as far as they possibly could. And the basis for this was a simple morality, rooted in sheer common sense and sound psychology. Asoka did not place the ascetic ideal before the masses. Love of family and home was his basis for them for righteous living. Asoka well understood that man is broad-based on the animal ; and so hunger and sex should have normal fulfilment in order that his people may be healthy and sociable, and not frustrated and anti-social. But he also understood that true worldly happiness lay only in such fulfilment of the organic urges as was tempered, purified and exalted by moral discipline and spiritual idealism.

And the people prospered in the reign of good King Asoka, and were happy, and knew peace for a whole generation as rarely before, if ever. Asoka knew that the peaceful reign of Right could endure only if served by Might—physical and moral Might. And some forty-two years after his accession, the mightiest, the noblest, and maybe the most lovable monarch of India, the foremost peacemaker of the world, passed to his eternal rest.

Within fifty years of the death of the Beloved of the Gods India was once more a jangle of warring nations For alas ! it is not permitted to one individual to establish the kingdom of heaven on earth for all time, unless all others freely co-operate. Since such individuals were wanting, India again experienced sorrow But that is of the essence of man's being—he can choose heaven or hell In the later Mauryan age, as in all ages as in our own times man betrays the highest in him

Asoka died But the memory of his unparalleled example lived in the hearts of men His name was ever on their lips from generation to generation and the Buddhist records perpetuated some of his achievement From the Volga to the Pacific Coast, from the steppes of Central Asia to the southernmost edge of the great Indian peninsula, and Ceylon, he was held in reverence But when fifteen centuries had passed and the Mussulman conqueror reigned in India, Buddhism was exiled from the land of its birth, and the memory of Asoka had sunk into oblivion And then, you from these British islands our youngest and in some ways our best-beloved cousins, from the remote west of Jambudvipa, the Old World, came in your youthful strength and overwhelmed us in the clash of battle Yet how lovely is the drama of destiny ! "The power that moves all things to good" decreed that your Warren Hastings, your William Jones and Colebrook, your Cunningham and John Marshall, your sons whose greatness lay in careful, painstaking scholarship, should restore to us our beloved, immortal Asoka and his beautiful deeds

So, the King lives ! He shines again like the central star of a great galaxy of kings !

R E Rock Edict K R E Kalinga Rock Edict

P E Pillar Edict

Geological Time.

By E. C. BULLARD, F.R.S.

" Time we may comprehend, 'tis but five days elder than ourselves."
Sir Thomas Browne, 1642.

I. *Introduction*

Hill and valley, land and sea, are the permanent, stable background of our lives The contrast between the unchanging landscape and the mutability of human fortune is a favourite theme of poets and philosophers. " Till a' the seas gang dry, my dear, and the rocks melt wi' the sun " is a synonym for eternity ; the rocks can never melt away, the seas are fixed for ever, such is the common opinion and experience of men.

There is, however, another side of the picture Though nature now appears so stable, the most casual examination of the rocks shows that things have not always been as they are Sea shells are found on the tops of mountains, the remains of trees at the bottom of coal mines and those of fishes in the middle of deserts Rocks that have clearly been formed as soft muds, and that still show the cracks formed when the mud dried and the ripple marks from the incoming tide, are found solidified to hard limestones and tilted and folded to form mountains

This contradiction of past change where all is apparently unchanging has, for us, a seemingly self-evident solution. Change is always going on, but is so slow as to be almost imperceptible in a lifetime, the time scale of geology is so vast that imperceptibly slow changes can unfold the story we see recorded in the rocks.

In spite of this simple and natural explanation, the dilemma proved harder to resolve than the much more subtle and less obvious truths of celestial kinematics and mechanics It is one of the strangest facts in the history of science that although the principles of astronomy and dynamics were firmly established and widely accepted in the sixteenth and seventeenth centuries, the true principles of geology were only laid down at the beginning of the nineteenth century.

Escape from the acceptance of a long time scale has been sought in many ways. Some have maintained that the fossils and other phenomena of the rocks are a deception and have

been generated by natural causes where they lie, or even that they were created as they are to deceive us or to try our faith. Of one such theory Leonardo da Vinci[1] wrote : " They tell us that these shells were formed in the hills by the influence of the stars ; but I ask where in the hills are the stars now forming shells of distinct ages and species, and how can the stars explain the origin of gravel, occurring at different heights and composed of pebbles rounded as if by the motion of running water ; or in what manner can such a cause account for the petrefaction in the same places of various leaves, seaweeds, and marine crabs ? " Such theories are quite unfruitful and the most that can be said for them is that the more theological forms are difficult formally to refute.

To-day no one doubts that, broadly speaking, the past was like the present, and that the evidence of the rocks is to be taken at its face value. In the words of Robert Hooke[2], " However trivial a thing a rotten shell may appear to some, yet these monuments of nature are more certain tokens of antiquity than coins or medals." If this is so, if present causes have cut the Great Canyon, dried the Sahara, and raised the Alps, then the time required must be of an order quite different from anything in our experience. Such a vast space of time was repugnant to human wishes in the same way as were the vast distances of the fixed stars required by Copernicus to account for their apparent lack of parallax. The realisation that there exist distances so great that no man can ever traverse them, and times much longer than the period of recorded history was critical in the development of our understanding of nature. However trivial it may appear to-day, it was, when it was made, a very hard step.

The purpose of this paper is to review the attempts that have been made to clothe the vast but vague expanse of time revealed by geology with numerical definiteness.

The most fundamental property of a chronology is that two events are either simultaneous or one is prior to the other.

[1]Lyell, C. *Principles of Geology,* 11th ed., vol 1, p. 31.

[2]Hooke, R. *Posthumous works, A Discourse on Earthquakes.* This interesting and scarce work has never been reprinted since it was first published in 1705 soon after Hooke's death

By this "before and after" relation events can be uniquely ordered in a series without any recourse to the numerical aspects of time. It is a time scale of this sort that is provided by ordinary geological methods. Over large parts of the earth's surface the rocks lie bedded one upon the other in almost horizontal layers. The natural inference from this is that these rocks are still lying in the order of their deposition and present us with a ready-made chronological series. Detailed examination shows us that this is indeed so, the mud cracks, the marks of rain drops, and the footprints of animals are all the right way up. More striking still, the fossils enclosed in the strata show a change that never goes backwards. Once a species is extinct it never occurs again in higher rocks.

Starting from such considerations, the story of a large part of the land surface of the earth has been pieced together, at any rate in outline. As Hooke hoped in 1688, "though it must be granted that it is very difficult to read them (the records of nature) and to raise a chronology out of them, ... yet it is not impossible". However, it is clear that the story, as a history, lacks something; it lacks dates. Besides its formal ordering property, time is metrical, its passage can be expressed in numbers. The methods of ordinary geology throw only the vaguest light on this aspect of the matter; they have not been able, as Hooke hoped "to state the intervals of the time wherein such or such catastrophes and mutations have happened". Sedimentation is fast in some places and slow in others, but "How fast?," or "How slow?," "How many years did the Jurassic last?" are questions whose answers cannot be read directly in the rocks.

II. *Denudational Methods.*

Before turning to radioactivity, which will probably in the end provide a real metrical time scale for geology, we may consider how far ordinary "common-sense" arguments can provide an estimate of the order of magnitude of the geological time scale. Such arguments consist in comparing the small changes that are known to have occurred in the last few hundred years with the vast changes in the past and by their ratio to

estimate the period required for the latter. Such arguments must be used with great caution. We tend to notice the exceptionally rapid changes, and to treat them as typical will clearly lead to a gross underestimate of the times ordinarily required for great changes. Further, the present is exceptional in that we have very recently emerged from an ice age and comparatively recently from a period of mountain building. With all these provisos, however, the question is still worth discussing.

Norfolk and Suffolk together lose about 36 acres to the sea each year[1], and at this rate it would take 60,000 years for the whole of these counties to be washed away. As this is an exceptionally rapid and conspicuous advance, and as such events may happen several times in a single geological period, it suggests that the length of a period must be reckoned in millions of years. Again, Niagara Falls are cutting their way upstream at a rate of about one foot each year, and at that rate would have taken 36,000 years to cut the 7 mile gorge at whose head they lie. The steep walls of the gorge, even at its lower end where it is oldest, show little signs of wear, and the gorge as a valley is obviously in its earliest youth. To produce a mature valley with gently sloping sides will require hundreds of times the period for which it has already existed as a gorge.

Such things are recurrent incidents in the history of a district and their duration is not very revealing as to the total extent of geological time. The repetition of erosion and sedimentation cycle after cycle, "the colossal hour glass of rock destruction . . . and rock formation" as Holmes has called it, is the fundamental process by which continents are built and destroyed; and it is these processes for which the time scale is really required. Some indication of the rate of denudation can be obtained by measuring the load of suspended and dissolved sediment carried by a river in a year and considering what average lowering of its basin is implied by this. There is a large literature on this subject, and the results, which are variable and subject to a great uncertainty, have been well

[1] *Royal Commission on Coast Erosion*, Vol. 3, p. 43, 1911; other parts of these countries are gaining land from the sea at a more than compensating rate.

summarised by Schuchert[1]. Here we merely give two examples :

River	Mass per year 10^6 tons	Catchment area, 10^6 sq. miles	Years to remove 1 ft.
Orange and Vaal above their confluence[2]	13	·035	1,500
Mississippi[3]	730	1·26	3,000

The average rate of erosion all over the world is probably substantially less owing to the existence of wide areas such as North Canada, that are low lying and suffer little denudation. The average rate for the whole of geological time will probably be still less, as the continents at present stand higher than at most periods in the past

Somewhere from 3,000 to 15,000 years to remove a foot would perhaps be a reasonable average, though it must be little more than a guess. At this rate it would take 9 to 45 million years to remove a 3,000 foot plateau such as that of South Africa, assuming that it allowed itself passively to be removed. Actually it would probably rise with the removal of load and the process might take several times longer.

All the sediment that is removed is deposited somewhere in the ocean, perhaps after an intermediate stage as a delta deposit. The areas of rapid deposition at any time are much smaller than the areas of erosion, though they move hither and thither in the course of time and presumably, in the long run, keep a balance in which the area of the continents neither loses nor gains on that of the oceans. The principal areas of deposition at present are the shelf seas which Holmes estimates to occupy 10 million square miles or an area equal to 13% of the land surface of the globe. If we make the rather dubious assumption that the places where most of the sediment was

[1]Bull. Nat. Res. Council, *The Age of the Earth,* 1931.

[2]du Toit, A. L. *The Geology of South Africa,* 2nd ed., p. 1, 1939, the mass per year is calculated from the other figures assuming a density of 2·2.

[3]Russell, R. J. *Louisiana Geological Survey, Geological Bulletin,* No. 8, p. 162, 1936.

deposited in the past occupied a similar area to that of the existing continental shelves, then the rate of deposition in these areas corresponding to a rate of denudation of 1 ft. in 3 to 15,000 years would be 1 foot in 400 to 2,000 years. The sum of the maximum thicknesses of all the sediments deposited in areas of rapid sedimentation since the beginning of the Cambrian is believed to be about 360,000 ft. The time interval required is, therefore, 140 to 700 million years. This is of the same order of magnitude as the interval found by radioactive methods.

Such arguments must not be pushed too far. The data from which the calculation starts are vague, and if the "right" answer is known it is not difficult to choose assumptions that will lead to it. Without reference to a time scale established in some other way no one can say within a factor of three what has been the mean rate of erosion in the past, nor over what area it has been distributed. All we can do is to use such arguments to show that the radioactive estimates of time are not absurd in relation to the scale and accepted mechanisms of geological change. The desirability of such a check is emphasised by the failure of Kelvin's apparently irrefutable attempt to calculate the time since the earth solidified by comparing the present downward increase in temperature with that calculated from the theory of the conduction of heat in a cooling globe.

III. *Radioactive Methods.*

Other "geological" methods of establishing a time scale are even less reliable than that depending on the rate of sedimentation. For anything like a reliable numerical estimate we must look elsewhere. Fortunately the slow radioactive decay of uranium and thorium provides a clock capable of recording these immense intervals. Both uranium and thorium decay at known rates to form lead and helium, passing on the way through a complicated series of transformations. The rate is uninfluenced by any conditions that can be produced in the laboratory and can safely be assumed to be independent of the less extreme conditions occurring in the outer parts of the earth. Thus, if a piece of pure uranium or thorium were placed in a gas-tight flask and the products examined at any subsequent

time the amount of lead or helium found would provide a measure of the time that had elapsed. Such considerations show that the decay of uranium and thorium may be able to provide a numerical time scale for geology. When, however, an attempt is made to apply such methods, and consideration is given to the conditions necessary for even a 10% accuracy, great difficulties are found, and the history of the subject is largely the story of unfulfilled expectations and unsuspected sources of error. Uranium and thorium are widely distributed in minute quantities through ordinary rocks, and are sometimes found concentrated in radioactive minerals. For a reliable age determination it is necessary that the uranium or thorium and one or both of their products should have remained since the rock was formed without gain or loss from any process other than radioactive disintegration. It is also necessary that either the rock should have been free from the products when it was formed or that it should be possible to distinguish the lead or helium formed by radioactive decay from that present initially. Finally, it must be possible to determine the quantities with the necessary accuracy.

The difficulties of fulfilling all these conditions simultaneously may best be shown by considering the magnitude of the quantities involved in typical instances.

Consider first an igneous rock such as the Whin Sill. Near the end of the Carboniferous or early in the Permian this rock was forced up from a deep lying reservoir of magma and spread through the overlying Carboniferous rocks where it solidified. The rock, like all igneous rocks, contains minute traces of uranium and thorium (0·8 gm. of uranium and 3 gm. of thorium per ton). This uranium and thorium was breaking up and producing helium and lead long before the rock solidified, but it is unlikely that much of the helium formed before solidification was retained, since experiment shows that molten rocks quickly lose their helium. Thus the condition of a start free from products is likely to be satisfied for helium. For lead it is most unlikely to be satisfied, since there is no process by which the lead formed in molten rock is likely to have been eliminated from the rock when it solidified. It is also possible that the rock contains lead not derived from the decay of uranium and

thorium. In fact, analyses of igneous rocks show that they almost always contain 100 to 1,000 times as much lead as could be produced by radioactive decay in any reasonable time, reasonable, that is, by comparison with other radioactive estimates. We must conclude, therefore, that the lead method cannot be applied to find the age of igneous rocks, and similar arguments show that it cannot be applied to sedimentary rocks.

IV. *Helium Method.*

For the helium method to be applicable the helium generated after solidification must be retained and it must be possible to measure the minute quantities concerned with sufficient accuracy. It is not the purpose of this paper to enter into the details of the technique of such measurements. Briefly, the amount of uranium present is estimated from the amount of radon in a sample. Radon is a radioactive gas formed as an intermediate stage on the downward path from uranium to lead. The amount present bears a definite ratio to the amount of uranium. It is excessively minute, the amount in a 10 gm. sample of the Whin Sill being, for example, 2×10^{-17} gm. Even in this minute amount of gas an atom disintegrates every 10 seconds, and these disintegrations provide the means of determining the amount of radon and thus of uranium present.

To get reliable measurements of such minute quantities naturally requires the most scrupulous care to avoid contamination with extraneous radioactive matter, and the most refined technique in the treatment of the specimens and in the measurement. A very thorough examination of the method has been made by Evans and others[1], and it is believed that the results now obtained are reliable. Unfortunately many earlier results are subject to errors whose magnitude it is difficult to estimate.

The estimation of the helium in a rock is, thanks to the beautiful method developed by Paneth, a cause of less difficulty than the radioactive measurements.

In recent years extensive series of age measurements have been made by the helium method. At first very promising

[1]Evans, R. D., Goodman, C., Keevil, N. B., Lane, A. C., and Urry, W. D., *Phys. Rev.* 55, 931—946, 1939.

results were obtained, particularly by Urry in the United States and by Holmes and his collaborators in this country and India. They found that consistent ages were obtained from rocks of the same geological period, and that a time scale could be built up that agreed with that obtained by other radioactive methods. They therefore believed that the escape of helium, which admittedly can occur under some conditions, was not a serious difficulty.

More recently the whole method has been subject to a searching examination by Keevil and others in Canada and the U.S.A. They showed that the loss of helium was much more serious and common than had been thought, and occurred in an unpredictable way so that it was never possible to tell whether a rock would give satisfactory results. In an attempt to escape from this difficulty they separated the minerals in the rocks and examined each separately. The ages obtained from the various minerals were systematically different. The feldspars, for instance, were found to give lower ages than most of the other minerals, and had therefore presumablv lost helium. As an example the following figures were obtained[1] from a cretaceous tonalite from Lakeview, California :—

	Apparent Age.	
Rock as a whole...	77	million years.
Quartz	74	,,
Feldspar ...	41	,,
Biotite	91	,,
Hornblend ...	200	,,
Apatite ...	43	,,
Zircon	23	,,
Sphere	30	,,

For a time it was hoped that satisfactory results could be obtained by working with certain selected minerals, particularly magnetite.

Unfortunately further work showed many exceptions and inconsistencies, and there seems now little doubt that the

[1] Larson, E. S., and Keevil, N. B., *Amer. Journ. Sci.*, 240, 209, 1942.

helium method cannot be used to determine the age of a rock within a factor of 2 or to build up a time scale. It may, however, be useful in certain cases to distinguish between two possible and widely separated ages, to decide for example whether an intrusion is tertiary or palæozoic when the purely geological evidence leaves this in doubt.

This failure to obtain satisfactory ages from the accumulation of helium in ordinary rocks is a disappointment and a sad ending to much careful and laborious work by an elegant and refined technique.

V. *Lead Method.*

We now turn to the consideration of radioactive minerals, that is, minerals containing a substantial proportion of uranium or thorium. A mineral such as the late Carboniferous uraninite from North Carolina may contain 80% of uranium, and 4% of lead, indicating, when combined with the rate of decay determined in the laboratory, an age of 230 million years. The amount of helium that would accumulate in the same time would be 18 $cm.^3$ per gm. of mineral. Now a gramme of the mineral only occupies 0·10 $cm.^3$, so that the helium would, if confined to this volume, produce a pressure of 18 atmospheres. Actually, the pressure would be many times greater since the 0·1 $cm.^3$ is already occupied by the mineral leaving only the interstices of the crystal lattice for the helium. It is clear that the mineral cannot stand such pressures and will crack and allow most of the helium to escape. This is confirmed by an examination of radioactive minerals, which are always extensively cracked, and which always contain less helium than would correspond to their uranium and lead content. From this it is clear that the age of a mineral containing a large proportion of uranium or thorium cannot be determined from its helium content. Unfortunately the shattering by helium generation can also adversely affect the age obtained from the lead content, as it assists the entry of water which may remove uranium or lead, and lead to too great or too small an age being obtained. A further difficulty is the possible presence of original lead. Galena is a not uncommon companion of uranium and

thorium minerals, and it is difficult to be certain that some of this extraneous lead has not entered into the analysis. The seriousness of these sources of error is not so much that they must always falsify the result, as that it is difficult to be certain whether or not they have done so in any particular instance. Sometimes there can be no doubt that they have occurred, for example, at Katanga in the south-east of the Belgian Congo pitchblend occurs in two varieties, a black and a yellow, the yellow being probably derived from the black. The ages found for two specimens of these are 580 million years for the black and 970 million years for the yellow. As the two types of crystal are intermingled it is almost certain that they are of the same age and that the yellow has lost uranium.

VI. *Isotopic Analysis.*

These two difficulties in obtaining reliable ages by the lead method may to some extent be avoided by a more detailed study of the lead formed. Ordinary lead, like most other elements, consists of a mixture of isotopes. That is to say its atoms, though all alike chemically, differ in mass. By means of the mass spectrograph, devised originally by Aston, it is possible to determine the proportion of atoms of the various masses present. In this way it has been found that all atoms have masses that are very closely integral multiples of a common unit a little lighter than the hydrogen atom. The integral parts of the masses in terms of this unit are called the "mass numbers" of the isotopes. Ordinary lead is found to be a mixture of 4 isotopes with mass numbers 204, 206, 207 and 208. A thorium atom has a mass number of 232 and loses 6 helium atoms each of mass 4 to give lead. The lead derived from thorium must therefore have a mass number of $232-6\times 4=208$. Uranium is a mixture of two isotopes, one with the mass number 238, being 139 times as abundant as the other with mass number 235. The more abundant isotope decays through the "uranium series" to lead of mass number 206 and the rarer via the "actinium series" to lead of mass number 207. These changes

are summarised in Fig. 1 and the constitution of the leads in Fig. 2. The general picture is well confirmed by the examination of the leads derived from radioactive minerals. A thorium mineral does give almost pure 208 lead and a uranium mineral a mixture of 206 and a little 207 (Fig. 3 A and B).

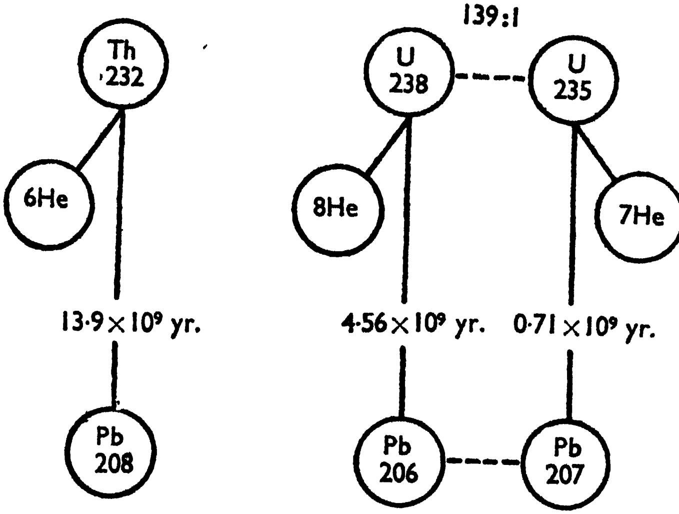


FIG 1 Initial and final stages in the disintegration of uranium and thorium, omitting all intermediate steps

From Fig. 2 it will be seen that 204 lead cannot be formed by radioactive decay. It therefore gives a measure of the amount of "common," that is non-radiogenic, lead present; and thus provides a way of avoiding one of the fundamental difficulties of the method. Unfortunately the proportion of the 204 isotope in ordinary lead is small, and its measurement with the mass spectrograph is not easy. A few years ago such measurements would have been considered quite unreliable owing to the presence of impurities, such as the hydrides of mercury, some of whose molecules have the same mass as the atoms of lead. By careful purification and attention to details of technique, A. O. Nier at Harvard has succeeded in overcoming these very formidable difficulties, and can now make satisfactory measurements on a few milligrams of lead in the form of lead iodide. As an illustration of the care necessary, it may be mentioned that the iodine used had to be specially purified from bromine

as the compound BrI has molecules of atomic weights 206 and 207 which would be confused in the mass spectrograph with lead.

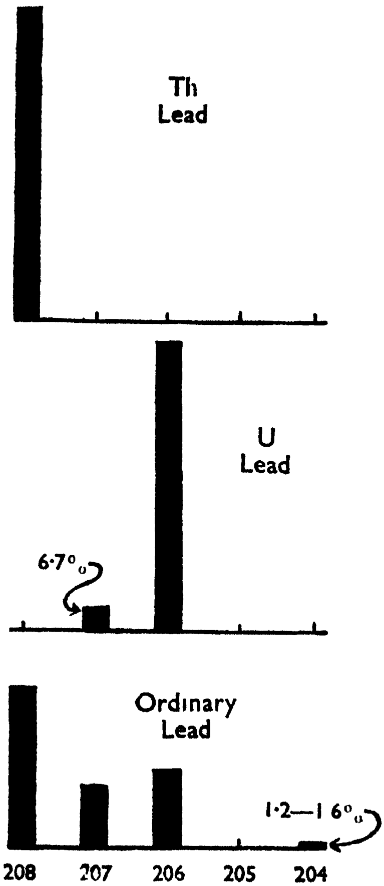


FIG. 2. Isotopic constitution of leads The proportions shown for U lead are for a lead that has been accumulating for the last 1,000 million years

If thorium is absent all the 208 lead must be lead of non-radioactive origin. In this case, therefore, it is not necessary to estimate the amount of such lead from the rare 204 isotope a determination of the 208 isotope is sufficient. Alternatively, a chemical atomic weight determination will give the same information. For in the absence of thorium, the radioactive

lead will be nearly all of mass number 206 (plus a little 207), and the chemical atomic weight will, if there is no common lead present, be near 206. The determination of the isotopes separately is, however, the more satisfactory process, as it also enables the other chief uncertainty of the lead method, that due to the leaching of lead or uranium, to be partially avoided.

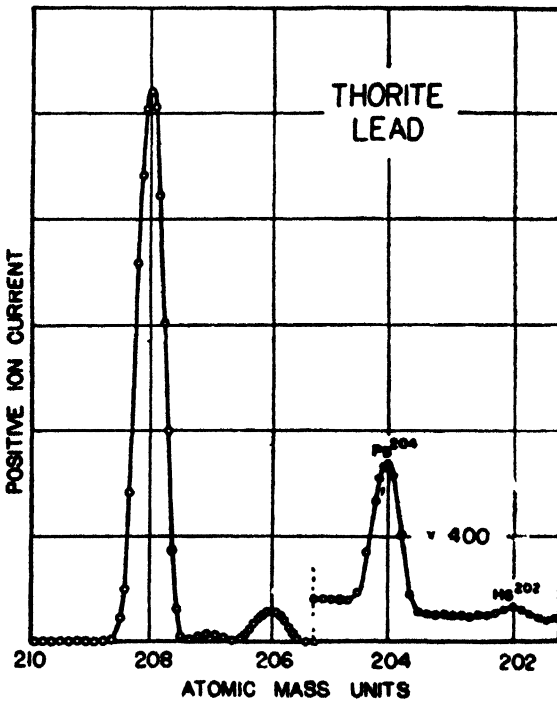


FIG. 3 A. Mass spectrum of nearly pure thorium lead from Norwegian thorite. The ordinate scale in the 204 to 202 region has been increased by a factor of 400. The width of the peaks is caused by instrumental limitations. From A. O. Nier, *Phys. Rev.* 55, p. 155, 1939.

The two isotopes of uranium decay at very different rates; whilst the atoms of mass number 238 take $4{\cdot}56 \times 10^8$ years to decay to half their number, the 235 atoms take only $0{\cdot}71 \times 10^8$ years. Thus the ratio of the abundance of these two isotopes will have varied in the past; at present 1/140 of all uranium atoms are of mass 235, 100 million years ago the proportion was 1 in 129 and 1,000 million years ago it was 1 in 62. With

this changing proportion of the two kinds of uranium atoms will have gone a change in the relative rate of production of 206 and 207 lead atoms. Thus the proportions of 206 and 207 lead atoms is a measure of the period during which the lead was formed. The ratio of the 207 to the 206 isotopes in lead formed to-day from uranium is 0·046[1], 1,000 million years ago

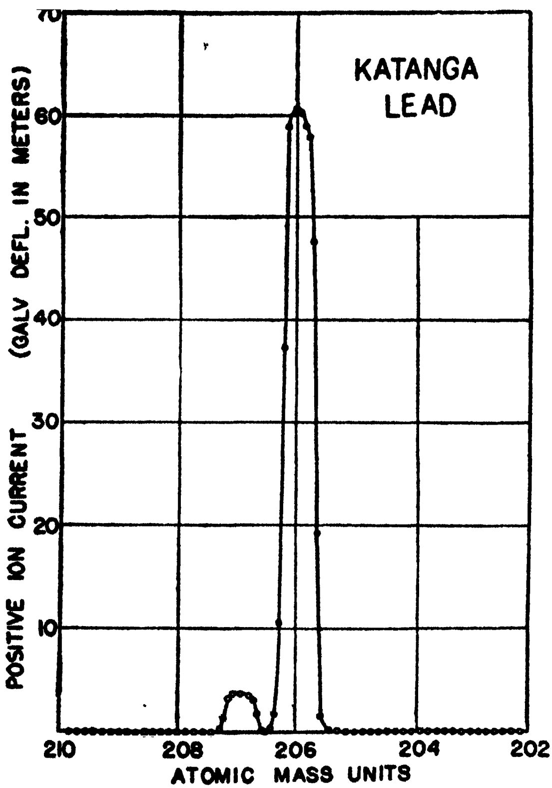
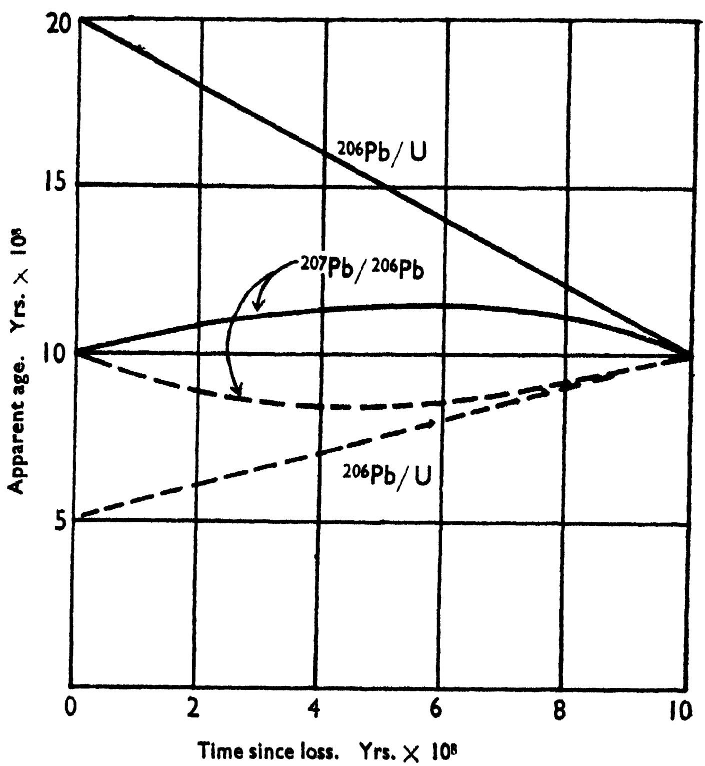


FIG. 3 B. Mass spectrum showing the isotopes of uranium lead from Katanga. From A. O. Nier, *loc. cit.*

[1]There is some doubt about this ratio and a corresponding uncertainty in the period of 235U. Laboratory measurement gives 0·040, Nier takes 0·046 to give agreement with the lead/uranium ratios as a whole. A detailed discussion of this rather complicated question would not be profitable at present, as Nier's remarkable achievement of separating perceptible quantities of the uranium isotopes (Nier, A. O., Booth, E. T., Dunning, J. R., and Grosse, A. V., *Phys. Rev.* 57, 546, 1940) is likely to lead to a better determination in the near future.



I IG 4 Apparent age of a rock with true age 10^9 years.
——50 % of U lost, — — — 50 of Pb lost.

it was 0·104. A mineral formed 1,000 million years ago will have been producing both leads throughout its life, and the lead found in it to-day will have a composition that is an average of that formed over the whole period; this average is 0·072. The proportion of 207 lead is thus a measure of age, and it is possible to calculate the age of a mineral from the isotopic constitution of its lead without any chemical data or any information about the amount of uranium present.

We now have three methods of obtaining the age of a mineral from its chemical analysis and the isotopic constitution of its lead,

(*a*) from the ratio thorium/208 lead;
(*b*) from the ratio uranium/206 lead;
(*c*) from the ratio 207/206 lead.

It is easy to show that the effect of the leaching of lead or uranium is much less for the third method than for the first or second (see Fig. 4), and thus if the methods agree it is strong evidence that leaching has not taken place to a serious extent.

There are, as yet, comparatively few minerals to which all these methods have been applied. The results that have been obtained are, however, promising, for example, a late Devonian uranite from Glastonbury, Connecticut, contains 6·91 % uranium, 3·05 % thorium, and 0·314 % lead. The lead has been found to contain the lead isotopes 204, 206, 207 and 208 in the proportion 0·167 : 100 : 7·60 : 21·3. From this it may be shown that 9 % of the lead is common lead, 12 % is derived from the decay of thorium, 75 % from the decay of uranium 238, and 4 % from the decay of uranium 235. These figures give the following fairly consistent ages by the three methods:

(*a*) from thorium and 208 lead, 266 million years;
(*b*) from uranium and 206 lead, 253 million years;
(*c*) from lead 206 and 207, 280 million years.

All minerals of ages between Cambrian and Tertiary for which an isotopic analysis of the lead has been made are included in Table 1, pre-Cambrian minerals are given in Table 2. The results are taken from Nier's papers. To these may be added the following results collected by Holmes[1]:

[1] *The Age of the Earth*, 1937, pp. 175–6

TABLE I.

Place	Mineral	Geological Period	Age—yrs. × 10^6 208 Pb/Th	207 Pb/U	207 Pb/206 Pb	Common Pb %
Woods Mine, Colo. ...	pitchblend	upper Cretaceous	—	57	—	47
Gilpin County, Colo. ...	,,	,, ,,	—	59	—	51
St. Joachimstal	,,	lower Permian	—	227	140	43
Brevig, Norway	thorite	,, ,,	235	243	—	4
Glastonbury, Conn. ...	samarskite	upper Devonian	266	253	280	9
Bedford, N.Y.	cyrtolite	upper Ordovician	—	361	375	3
,, ,, ...	,,	,, ,,	—	341	300	6
Güllhögen, Sweden ...	kolm	upper Cambrian	—	388	770	4

TABLE 2.

Place	Mineral	Age—yrs. × 10^6			Common Pb %
		208 Pb/Th	207 Pb/U	207 Pb/206 Pb	
Parry Sound	thucholite	240	260	430	2
Beaver Lodge	pitchblend	—	330	460	4
Ceylon	thorianite	460	530	480	0
Morogoro	uraninite	—	800	600	0
Katanga	pitchblend	—	620	610	0
,, ...	,,	—	580	620	0
,, ...	,,	—	—	610	0
Besner, Ont.	uraninite	790	760	820	0
Pieds-des-Monts	cleveite	—	880	900	3
Parry Sound	uraninite	940	1,000	1,030	0
Wilberforce	,,	980	1,080	1,030	1
Norway	cleveite	840	1 080	1,090	0
Mt. Isa, Australia	monazite	1,000	—	1,190	3
Las Vegas, New Mexico	,,	770	1,730	1,340	2
Gt. Bear Lake	pitchblend	—	1,250	1,420	4
Huron Claim...	monazite	1,830	3,180	2,570	1

TABLE 3.

Place	Mineral	Geological Period	Age 10^6 years
Mexico	uraninite	upper Tertiary	34
Idaho	brannerite	,, ,,	35
Japan	ishikawaite	Jurassic	123
North Carolina...	uraninite	upper Carboniferous	232
Silesia	pitchblend	lower Carboniferous	269
Fitchburg, Mass.	uraninite	upper Ordovician	349
Branchville, Conn.	,,	,, ,,	371

No isotopic analyses are available for the lead from these minerals but it is considered that there is a good chance of their being reliable.

Fig. 5 gives a general view of the agreement between the ages obtained by the three methods. The ages from the ratio of the lead isotopes are plotted as abscissæ, and those from the Pb/U and Pb/Th ratios as ordinates. All Nier's measurements are included except those on four specimens that are definitely known to be alteration products. There are some large discrepancies particularly for the older specimens. The point giving 770 million years from the lead ratios and 390 from the Pb/U ratio is that obtained from the upper Cambrian Swedish kolm. The discrepancy presumably means that this has been altered and cannot give a reliable age. This is particularly regrettable as it is the oldest specimen that can be accurately placed from geological evidence. The diagram and Table 1 indicate how far we still are from a satisfactory time scale.

Perhaps the best chance of progress is the study of heavy minerals, particularly zircon, from igneous rocks. It is probable that it would be possible to separate from many rocks fractions

with radioactivity sufficiently great to prevent contamination with ordinary lead being a serious source of error. If this were so it would considerably widen the field that could be studied and it is probable that leaching would be less serious than in a mineral containing a large proportion of uranium.

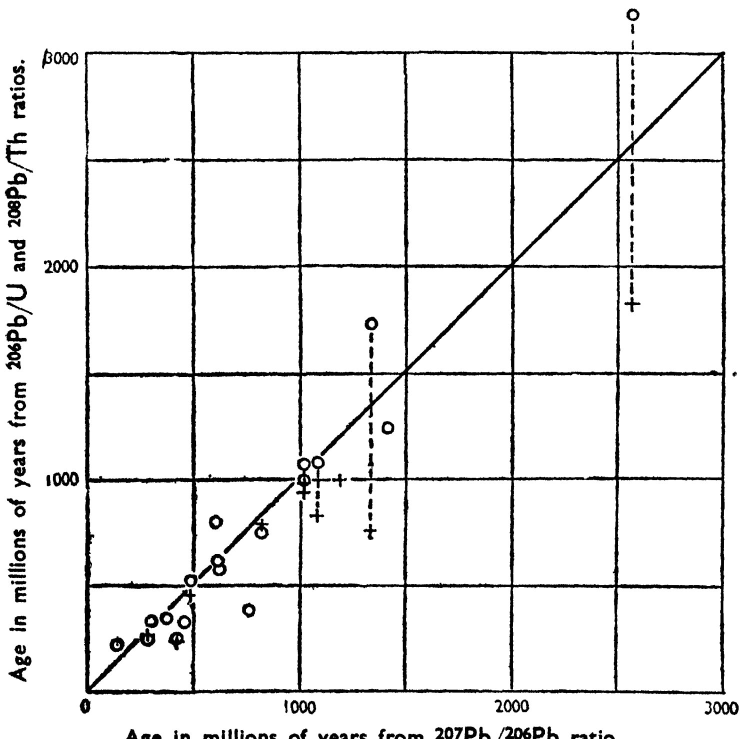


FIG. 5. Comparison of ages octained by different methods
O Ages from $^{206}Pb/U$. + Ages from $^{208}Pb/Th$.

VII. *The Time Scale since the Cambrian.*

The results given in Tables 1 and 3 above are too few to give more than a very general idea of the length of the various periods. Even with this slight data, however, we may get some interesting results. In Fig. 6 the ages are plotted against the maximum thickness of the deposits accumulated in each period as estimated by Holmes[1]. These maximum

[1] *The Age of the Earth,* 1937, p. 51.

thicknesses are nearly all measured in mountain systems standing on the sites of earlier geosynclinal troughs ; in places, that is, where the crust has slowly sunk allowing many thousands of feet of shallow water sediments to accumulate. The thicknesses are therefore not so much a measure of the maximum rate of sedimentation as of the rate of subsidence occurring in a geosyncline. If subsidence proceeded more slowly the trough would fill in and the surplus sediment would be carried elsewhere, if it were faster deposition could probably in most places keep pace with it.

The points in Fig. 6 lie, considering all things, remarkably well on the straight line corresponding to 1,180 years/ft.[1] This fit with a straight line is a Uniformitarianism more literal

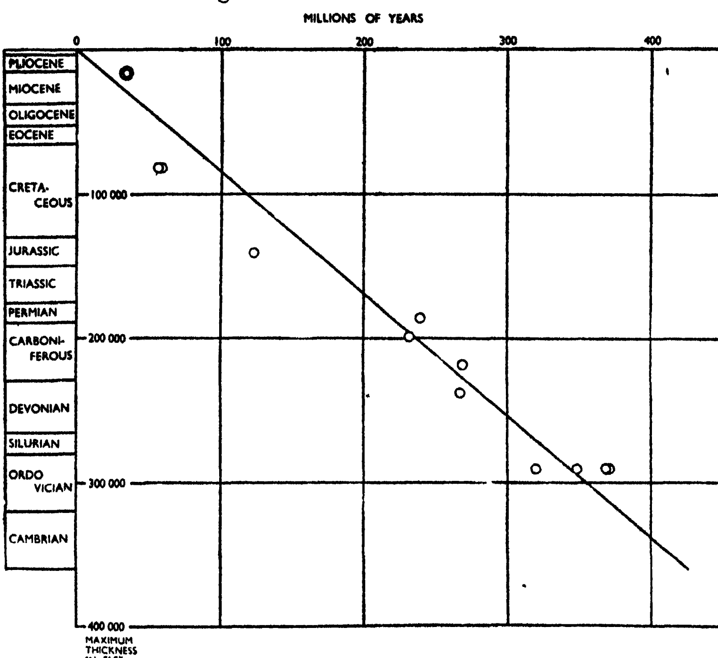


FIG. 6. Progress of Sedimentation since the Cambrian.

[1]This value has been obtained by assuming that "late Devonian" means ⅘ of the way through the Devonian, and similarly for other qualitative statements in column 2 of Table 1. The standard error is 40 years/ft. The results for Joachimstal pitchblend and Swedish kolm have not been used in this calculation as the results given in Table 1 are discordant.

than most followers of Lyell would demand. If it is really a fact and not an appearance due to the chance agreement of inadequate data it means that the crustal sinking which precedes mountain building has progressed at the same uniform rate ever since the Cambrian, and through three distinct major periods of mountain building. In view of the inadequacy of the data this can be little more than a plausible speculation at present.

Table 4 gives the lengths of the geological periods assuming Holmes's thicknesses and taking 1,180 years/ft. as the rate of deposition The method by which this is obtained is admittedly open to great uncertainty, but it is probably the best method of using our slender stock of radioactive results to give a complete time scale.

TABLE 4.

Period	Max. thickness ft	Duration yrs.	Time since start yrs.
Quaternary... ...	4	(5)	(5)*
Pliocene	13	15	20
Miocene	21	25	45
Oligocene	15	18	63
Eocene	14	16	79
Cretaceous	64	76	155
Jurassic	20	23	178
Triassic	25	30	208
Permian	13	15	223
Carboniferous ...	40	47	270
Devonian	37	44	314
Silurian	15	18	332
Ordovician	40	47	379
Cambrian	40	47	426

VIII. *Pre-Cambrian Time.*

Table 2 gives Nier's results on pre-Cambrian minerals; certain obviously altered ones have been omitted. The data

*The Quaternary is included to complete the table, but, owing to the Ice Age, conditions were altogether exceptional and the duration deduced cannot be regarded as having any geological interest.

are as yet insufficient for a discussion of the correlation of pre-Cambrian rocks between the continents, though this is perhaps the major problem in the solution of which age data can assist. In a general way the results suggest ages of 400—600 million years for the upper pre-Cambrian, including rocks such as the Keweenawan of Canada and the rocks containing the Katanga uranites. The oldest known rocks give ages of 2,000—3,000 million years.

IX. *The Nature of Time.*

In all the above arguments we have adopted a very naïve attitude to the subject. It has been assumed that what is meant when we speak of a thousand million years is as clear and self evident as what is meant when we speak of 10 days, and that to say that the rate of disintegration of uranium is constant is necessarily a significant statement, and moreover, one that is almost self-evidently true.

Logically, perhaps, we should have started with a discussion of how time can be measured and of the assumptions involved. Reversing the order provides, however, a concrete background for the more abstract discussion.

The siderial day is ordinarily defined as the time of rotation of the earth relative to the line of intersection of the equator and the ecliptic. Although this is the practical definition it is not a very fundamental one. There is no contradiction in discussing whether the earth is slowing down under the influence of tidal friction or from some other cause. The earth is used as a time measurer merely because it is the nearest approach that we have to a freely rotating body. The desire to use a freely rotating body derives from the fact that in Newtonian mechanics it has a constant angular velocity. Thus, if we define the measure of any interval of time to be proportional to the angle turned through by the earth in that interval, then we can expect to be able to use that time in the Newtonian dynamical equations to obtain correct predictions about the motion of bodies. Discrepancies between such predictions and observation will mean either that the earth is not a sufficiently free body or that Newtonian mechanics does not give a completely accurate

description of phenomena. The first alternative raises no difficulty in principle; we can either choose some other body, such as the moon, an oscillating quartz crystal, or a pendulum, or we can discover and allow for the disturbing forces acting on the earth.

So long as we are satisfied with our dynamics this method of measuring time is self-consistent and satisfactory, but it is not unique. It would be possible to start from many other bases. For example, our measure of a time interval might be the distance travelled by light in the interval, or the cooling of a heated body in free space, or the rate of a chemical reaction under specified conditions, or the rate of decay of a radioactive body, or many other alternatives.

A large part of physics consists of the establishing of relations between such processes and many of the laws of physics could be stated in the form of recipes for constructing and graduating clocks in such a way that they will tell a time that is consistent with the Newtonian time. For example, if we take W gm. of uranium and at a subsequent time have w gm. left, then if the time elapsed is taken as $0{\cdot}66 \times 10^{10} \log W/w$ years, the time obtained will be consistent with that kept by the Astronomer Royal.

Such laws are the result of experiment generalised by a framework of theory. Our experiments, however, are confined to the present and the recorded past, and we must admit the possibility that the laws derived are only an approximation valid over a limited period and that the various clocks may diverge if extrapolated over too long a time, just as mercury and alcohol thermometers disagree if compared over a large range of temperature. On the other hand, it would be unwise to assume that the laws and constants of physics have changed in a capricious way in the past; that sound guide "Occam's razor" suggests that we should not wantonly assume changes until they are positively required by observation or theory.

It may be said at once that there is nothing known from the rocks themselves that compels us to assume a change of the kind we are discussing. It is not possible to judge the age of a rock from its appearance; the physics and chemistry of rock

decay and formation appear to have been the same throughout recorded time, the ripples and the marks of rain drops preserved in the rocks can be exactly paralleled to-day. Fortunately a numerical test is possible in one case. The helium atoms or α-particles shot out by minute specks of radioactive matter in mica and other minerals produce a darkening of the mineral which is especially marked near the end of their flight. By examining the "pleochroic haloes" produced by this process it is possible to determine the ranges of the α-particles emitted over a period of a thousand million years and to compare them with laboratory measurements. "Time which antiquates antiquities and hath an art to make dust of all things, hath yet spared these minor monuments," as Sir Thomas Browne said of less ancient remains.

The comparison has been made with great care by G. H. Henderson, one of whose photographs is reproduced in Plate I. He could find no difference between the radii of the rings in early pre-Cambrian micas and in those produced to-day.

The meaning of this result is worth considering in some detail. The speed with which an α-particle is ejected depends on the forces within the nucleus of the atom, forces, that is, whose main effect is confined within a range of the order of 10^{-13} cm. The forces stopping the α-particles are of quite a different kind, they are the forces between it and the electrons and nuclei of the mica at distances of the order of 10^{-8} cm., these forces are of the same kind as ordinary chemical forces. If there were any change in the fundamental constants of physics it is just the relation between such different kinds of forces that might be expected to change.

On the theoretical side there is sufficient uncertainty to leave room for wide speculation. All cosmologists are agreed that the universe, that is the system of galaxies, is expanding, and that the relative rate of recession between an observer and a galaxy is, on the average, proportional to their distance apart. If this state of affairs has persisted in the past; that is if the law of proportionality of distance to speed of recession holds not only for all the galaxies at one time of observation, but also for one pair of galaxies at all times; then, as we go

back in time, the universe will become smaller and smaller and more and more crowded with matter. Current cosmologies differ in the extent to which they carry this process back, at one extreme Le Maitre supposes the universe to start as a single enormous atom, at the other Eddington supposes a nearly stable initial state with a finite radius. All theories agree that about 2,000 million years ago was a critical date, and for most of them dates before this have no meaning. This critical date is derived entirely from the rate of recession of the galaxies determined from their spectra. It is remarkable that it is of the same order as the age of the oldest minerals determined from radioactivity.

The numerical coincidence presumably means that the earliest known rocks were formed not long after this critical date ; that is, we probably have a record of most of the earth's history. Such a conclusion is not unplausible since the conditions may well have been more favourable to the production of planetary systems when the universe was more compressed.

Milne has developed his theory of " Kinematic Relativity " to a point where conclusions can be reached as to the past changes in the laws of physics. It is not possible to discuss his views in detail here,[1] but the result is that many of the " constants " do change when a period comparable with the critical age of 2,000 million years is considered. In particular, he predicts that a radioactive and a dynamical clock will diverge more and more as we go back, and that the critical date of about 2,000 million years B.C. by the radioactive clock will be indefinitely remote by the dynamical clock.

There is at present no general agreement about these matters, but the mere possibility of such views being advanced by competent cosmologists suggests that it is necessary to consider seriously the possibility of pre-Cambrian physics being in some ways different from our own. The evidence from the pleochroic haloes is against this, but it is not necessarily conclusive.

From this point of view geology is a more " fundamental " science than is sometimes realised. There are two ways to

[1] J. B. S. Haldane has published some interesting speculations (*Nature*, 153, 555, 1942) on the possible geological and biological consequences of Milne's views.

examine the universe in its childhood; we may look at stars so distant that the light emitted early in their career has only just reached us, or we may look at the pre-Cambrian rocks, some of which may contain a cosmological record just as important as that given by astronomy. Our knowledge of pre-Cambrian theoretical and experimental physics is meagre but it is not necessarily impossible to increase it.

X. *Conclusion.*

It is impossible to write on this subject without plagiarising Prof. Holmes. This paper is no exception in this respect; its only justification is that since Holmes last wrote there have been two experimental advances of first class importance. First, the work of Keevil has cast doubt on the whole helium time scale, and second, the work of Nier has given a new definiteness to that derived from lead. These advances I hope justify a new discussion.

The Phytoplankton of Some Cheshire Meres

By EDNA M LIND

In earlier numbers of this Journal, there appeared three papers dealing with the natural history of Rostherne Mere. The earlier two, by Tatersall and Coward (1918) comprised a faunal survey, while the later one, by Pearsall (1923) gave an account of the phytoplankton and attempted to relate it to the chemical composition of the water

In subsequent years, our knowledge of the biology of lakes has been much extended by workers in America, on the continent and in this country where most consideration has been given to the lakes of the English Lake District Little further attention has been paid, however, to the Cheshire Meres, or indeed to any of the lowland waters of this country, and it seemed desirable to extend the investigation begun on Rostherne to some other lakes of the Cheshire plain In this paper, several of these meres are described and an attempt is made to relate their phytoplankton to the chemical composition of the water and to compare them with the lakes of more mountainous districts

In order to appreciate fully the significance of the results obtained, it is necessary to know something of the general story of algal periodicity and distribution in relation to the composition of the water, as this has been elucidated in other lakes and in particular in those of the English Lake District Algæ, like all other green plants, absorb their nourishment in the form of a dilute solution of inorganic salts and also carry out photosynthesis utilising the CO_2 dissolved in the water There are two sources of inorganic food, the salts brought in by inflowing streams and drainage water, and the materials resulting from bacterial decomposition of plant and animal remains in the mud on the lake bottom It will be clear that a lake lying in a basin of hard rock and surrounded by steep mountain slopes like Wastwater will be much poorer in nutrient salts than a lake like Windermere which lies in a region of softer slates, has a good deal of cultivated land round its shores and receives considerable quantities of silt. Further, the rocky type of lake, being poor in nutrients, supports a smaller crop of plankton and therefore forms less organic mud The nature of the phytoplankton also differs in the two types of lake,

being composed largely of desmids in the rocky type and of diatoms and Myxophyceæ in the silted, while lakes of mountainous districts have some species which are quite unknown in lowland waters. The Cheshire Meres represent a type of lowland lake, very much more heavily silted even than Windermere, rich in nutrients and supporting abundant plankton.

A feature characteristic of all lakes is the seasonal periodicity of the phytoplankton. In the case of the silted lake, diatoms are abundant in winter and spring and as these decrease their place is taken first by Chlorophyceæ and later by Myxophyceæ. These changes in the composition of the plankton are associated with a variation in the amount of nutritive substances in the water. One of the most important is nitrate, which is usually high in winter but falls off rapidly towards summer as it is utilised by the plankton crop. A flood temporarily enriches the water with nitrate washed in from the surrounding land and the supply is replenished by the products of bacterial decay as well as by inflowing streams. The growth of diatoms is favoured by the presence of nitrate and silica, while their death and decomposition in the summer months enrich the water with organic nitrogen. A good supply of organic material is apparently favourable to the Myxophyceæ, whose maximum occurs in autumn. Phosphate, which is also essential to the growth of algæ, is always adequate in lakes of the silted type.

In the account which follows, some attempt is made to relate the composition and periodicity of the phytoplankton of the Cheshire Meres to the general conditions for English lakes as outlined above. The survey was begun when a car made frequent and regular collections possible, and it was intended to follow the periodicity of the phytoplankton at short intervals throughout the year. Preliminary visits were paid at intervals of three months from autumn, 1941, to summer, 1942, to Rostherne, Redesmere, Budworth Mere and Hatchmere, and plankton samples were examined to discover which of these waters would repay further attention. As the plankton of Rostherne and Budworth seemed to show the greatest differences, water samples from these two lakes were analysed. When difficulties of transport made frequent and regular visits impossible further collections were made in the spring and

late summer only from all four meres The earlier time was chosen as being at the close of the spring diatom phase and the later as representing the period when the products of decomposition of spring and summer growth would be apparent At the same time analyses of the water were made at the Public Health Laboratories Oakmere was added to the list of lakes examined in 1943

Description of the lakes

Rostherne Mere lies on the estate of Lord Egerton of Tatton between Altrincham and Knutsford, about ten miles S W of Manchester It is about 115 acres in extent and in some parts reaches a depth of 100 feet The mere lies in a deep basin in the Triassic Red Marl which is locally said to have been formed by subsidence due to the withdrawal of brine from the underlying rocks which form the lake bottom At the nearest salt workings, at Agden some two miles distant brine is pumped from a depth of 500 feet, suggesting that the salt deposits are well below the level of the lake floor It would seem likely that the mere simply occupies an unusually deep basin in the glacial drift not necessarily due to subsidence The north end of the lake, however, is occupied by a peat bog now submerged to a depth of 14 feet, and this subsidence must clearly have happened in post-glacial times It is also significant that during the last ten years a small new lake has appeared due to subsidence in Tatton Park, and this already has a plankton similar to that of Rostherne itself

The topographical features of the lake have been fully described by Tatersall and Coward (1918) It is fed by several small streams, the largest of which rises in Tabley Moss, about two miles to the south and flows first through Mere Mere, a sheet of water suffering considerable pollution from the houses on its banks Blackburns Brook, the outflow stream, flows through a willow bed and its fall is so slight that it has been observed to flow back into the mere when the level of the stream is high after floods The banks are occupied by woods and farm land and the greater part of the margin by a fringe of reed swamp consisting mainly of *Phragmites*. Access to the mere is strictly limited and its waters are uncontaminated. Fish, particularly perch and pike, are plentiful and Rostherne

is the only locality in Britain for the smelt, normally a salt-water fish but found in some of the freshwater lakes in Sweden.

Budworth Mere.

Budworth Mere was selected for study because it lies in the salt mining area centring on Northwich and Middlewich. It has again been suggested that it lies in a subsidence basin, though the general topography of the lake does not suggest this. It is fed by a stream flowing in from Pickmere, a lake about one mile distant and used for pleasure boating. The mere is surrounded mainly by agricultural land, with a few pieces of woodland. Reed swamp is well developed, especially at the shallow western end where an area of reed bed and woodland is preserved as a bird sanctuary in memory of the Cheshire naturalist T. A. Coward. The lake is 80 acres in extent and reaches a maximum depth of 22 feet, with an average depth of 6 feet at the shallow western end and 13 feet at the eastern end.

Hatchmere.

Hatchmere is situated in Delamere forest near the village of Norley. The underlying rocks of Keuper sandstone are overlaid in this district by glacial sands and gravels, and Hatchmere occupies a basin in the drift 16 acres in extent and about 16 feet deep at its deepest part. It is fed by a sluggish stream which nevertheless brings down considerable silt, and there is a small outlet stream. The mere is rapidly silting up, especially at the north end which is occupied by a wooded fen passing into a *Molinia-Myrica* bog. The area of open water is now only one-third of its former size and a reed swamp of *Phragmites* and *Typha angustifolia* is still encroaching. The bank on the west side is covered with shallow peat bearing *Calluna vulgaris*, and along the east and south sides run roads with a number of houses from which the water doubtless receives some pollution. The chief features of the lake as a habitat are its heavily silted nature, the peaty influence and the possibility of pollution.

Redesmere.

Redesmere lies just off the main road from Manchester to Congleton about a mile beyond Monks Heath on the estate of

Sir William Bromley Davenport. The lake is 60 acres in extent and is nowhere more than 16 feet deep. The rather narrow, shallow part at the western end is said to be an artificial extension of the original mere. The stream flowing in through the grounds of Fanshawe brings down considerable silt, on which a fen vegetation has become established, and reed swamp consisting of *Phragmites* and *Typha latifolia* is well developed in the sheltered bays. Pasture land surrounds the lake on all sides and an outlet stream drains into the lake in the grounds of Capesthorne Hall.

Oakmere.

The last mere to be described is of quite a different type to the other four. Oakmere lies in Delamere Forest near the road between Kelsall and Winsford. It is 52 acres in extent and reaches a maximum depth of 18 feet. It now serves as a reservoir for the town of Winsford.

Like Hatchmere, which lies some three miles distant, Oakmere is to be regarded as a depression in the glacial sands which has filled with water. Unlike Hatchmere, however, it has neither inflow nor outflow, but is fed by springs rising through the gravel bed. Over the original bed of the depression there now lies a covering of submerged peat which is overlaid round the shore with sand from the surrounding drift. When the water level is low, some of the peat is exposed, revealing the bases of trees. It is evident that this depression has refilled with water since the formation of the peat, and expert evidence given fifty years ago in connection with brine-pumping in the district suggests that the natural level of the water in the depression fluctuates rapidly. There is no reed swamp, but the exposed areas of shore are rapidly becoming covered with a dense growth of *Juncus effusus*, the growth being strongest where no flooding occurs. *Molinia* predominates round the peaty margin of the basin.

Composition and periodicity of plankton.

The percentage composition of the phytoplankton throughout the year is shown in Table 1. It will be well to consider first the four lakes with similar situation and surroundings and deal separately with Oakmere.

TABLE I.

Percentage composition of phytoplankton

	ROSTHERNE						HATCHMERE						OAKMERE		
	Autumn		Winter	Spring		Summer	Autumn		Winter	Spring		Summer			
	28/8/41	9/8/43*	15/12/41	25/3/42	5/4/43	29/6/42	1/10/41	23/8/43*	31/12/41	3/42	31/3/43	28/6/42	23/8/43	7/10/42	31/3/43
Diatoms	8·5 A.	8 A.	66 A.	91 A	21 A.Co.	2	2	2	99 A.	98 A.	95 A.	24 A.F.	+	40 C.	+
Myxophyceæ ...	2	8	32 CK.	3·5 CK.	17 CK.	17·4 An.	99 Aph. CK.	85 CK.	+	1·8	0	11 M.CK.	+ CK.	5 An.	0
Chlorophyceæ ...	4 Sph.	·5	0	+	1	57 E.	6·5 Dict.	11 Dict	+	+	1·5	13 T.	96 B.	50 B.	99 B.
Desmids	·5	+	2 Cl.	4.5 Cl.	2	+	1	1	+	+	+	1	0	0	0
Ceratium	87	83·5	+	+	59	23.6	+	+	0	+	3	40	0	0	0

TABLE I—*contd.*

	REDESMERE						BUDWORTH								
	Autumn		Winter	Spring		Summer	Autumn		Winter	Spring		Summer			
	13/9/41	2/8/43*	29/1/42	4/3/42	4/44/3	19/7/42	27/8/41	16/7/43*	15/12/41	25/3/42	1/5/43	28/6/42			
Diatoms... ...	20·2 A.	3	10 A.	17	77·5 A.	14 Mel.	87 Mel.	38 A.Mel.	15 A.Mel.	96 A.	93 S	1			
Myxophyceæ...	73.2 M.	55·5 M.CK.	87 M.	68 M.	50	83·5 M.Aph.	6 O.	53 Aph. CN	2	+	2	0			
Chlorophyceæ	6·1 Sc.	27 Dict.	3	15 Sc.	15·5	2·5	5·5	15 P.	4·5 P.	3 P.	4 Sc.	93 C.			
Desmids... ...	+	1·5	0	+	2	+	+	3	78 Cl	1 Cl.	1	6			
Ceratium... ...	+	0	0	0	0	0	+	+	+	0	0	0			

Abbreviations.

A. Asterionella. Co. Coscinodiscus. M. Melosira.
F. Fragilaria. S. Synedra. C. Ceratoneis.
M. Microcystis. CK. Coelosphaerium Kützingianum.
Aph. Aphanizomenon. An. Anabaena. O. Oscillatoria.
CN. Coelosphaerium Nágelianum.
Sc. Scenedesmus. T. Tetraspora. Dict. Dictyosphaerium.
P. Pediastrum. C. Chlamydomonas. Sph. Sphaerocystis.
B. Botryococcus. Cl. Closterium. C. Ceratium.
* Vertical haul.

In the autumn of 1941, when the first collections were made, Redesmere and Hatchmere were characterised by an abundance of Myxophyceæ, together with some diatoms and about five per cent. of Chlorophyceæ. In Rostherne the very great abundance of *Ceratium hirundinella* almost masked the presence of Myxophyceae which were nevertheless there in quite considerable quantity. In Budworth at this time eighty-seven per cent. of the plankton was composed of the diatom *Melosira granulata*. Autumn 1943 showed much the same situation except that Budworth had more Myxophyceæ and fewer diatoms and *Asterionella* had largely replaced *Melosira.*

By December diatoms had increased. In Rostherne Myxophyceæ had also become more apparent as *Ceratium* decreased. Redesmere still showed abundant Myxophyceæ and in Budworth there was an unusual predominance of the desmid *Closterium gracile.*

Spring, 1942, was marked by a high percentage of diatoms in all lakes except Redesmere where Myxophyceæ still predominated, but in 1943 Redesmere also showed a spring diatom maximum. Following a mild winter, in April 1943 the change to summer conditions had already begun in Rostherne with its decrease in diatoms and rise in *Ceratium*.

In the June collections, diatoms had fallen off considerably, reaching only one per cent. in Rostherne and Budworth. Myxophyceæ were few except again in Redesmere, but Chlorophyceæ formed a conspicuous part of the plankton and *Ceratium* was on the increase.

It will be seen then that the phytoplankton of these waters follows the general type of seasonal periodicity characteristic of English lakes. Diatoms in the winter and spring give place to Chlorophyceæ and Myxophyceæ in the summer with a maximum of the latter in the autumn. Desmids are represented by *Staurastrum paradoxum* var *longipes* and var *biradiatum, St. gracile,* and species of *Closterium.* Except in the *Closterium gracile* maximum in Budworth they never form a conspicuous part of the plankton.

The collections were made with a fine silk net (70 meshes per cm.), wherever possible from a boat. The percentages given,

are the proportions noted from counting at least 300 individuals. Where one species was very abundant, as in the case of *Ceratium* in Rostherne, the percentage of other groups appears very low, though actually the quantity in the lake was quite considerable.

Special features of the plankton.

The plankton of each lake showed special features of interest.

Rostherne.

Rostherne was remarkable for the abundance of *Ceratium hirundinella.* Further, the present collections differed in the following respects from those made by Tatersall and Coward in 1913–14 (Table 2) : –

(*a*) *Staurastrum paradoxum* was absent, and the species was represented only by the varieties *longipes* and *biradiatum.*

(*b*) *Fragilaria crotoniensis* was inconspicuous.

(*c*) *Asterionella* was more abundant in winter and less so in summer.

(*d*) *Coelosphaerium Kützingianum* replaced *Aphaniozomenon* as the dominant constituent of the Myxophyceæ. As, however, the latter Alga reached its maximum in October in 1912, it is possible that the maximum was missed in 1941 when no collection was made between August and December.

Griffith's data for 1922 (Griffiths 1925–27, No. 3) resemble the 1912 samples rather than the recent ones. Some of the variations between the different collections, as for example the amount of *Asterionella,* may be purely seasonal ; but others suggest a change in the conditions of the lake. The form of *Staurastrum paradoxum* found by Tatersall and Coward and described by Pearsall (1923) is one which is common in the lakes of the West of Ireland (Pearsall and Lind, 1942) and of the English Lake District. In all the Cheshire Meres it is now replaced by the varieties and it is possible that the true *St. paradoxum* cannot stand the heavily silted condition which now obtains in these waters.

Hatchmere.

Hatchmere bears a certain resemblance to Rostherne, particularly in regard to the presence of *Ceratium* (forty per cent.) in summer and to the composition of its Myxophyceæ and diatom components. The high maximum of *Asterionella* in

TABLE II.

	1912 17 Dec.	1941 15 Dec.	1913 22 Mar.	1942 25 Mar.	1913 28 June	1942 29 June	1912 17 Aug.	1941 28 Aug.	1922 Aug.
Staurastrum paradoxum	20	0	+	0	+	0	+	0	C.
St paradoxum var bi-radiatum... ...	0	+	0	0	0	0	0	·5	+
Closterium aciculare var subpronum...	7	1	+	5	+	0	+	0	subdom.
Botryococcus Braunii	10	0	+	+	0	6	0	+	
Asterionella formosa	8	66	2	89	9	+	3	6	+
Fragilaria capucina	1	0	+	+	31	+	0	0	
Fragilaria crotoniensis...	8	0	+	0	+	+	35	0	dom.
Coscinodiscus lacustris	32	+	95	2	2	0	0	1	
Coelosphærium Kützingianum	2	32	+	4	+	+	0	1	
Microcystis spp.	0	+	0	+	0	5	+	+	+
Aphanizomenon flos-aquae...	1	0	+	0	+	2	5	+	
Ceratium hirundinella	1	+	2	+	55	24	50	87	C.

Comparison of Rostherne collections of 1912–13, 1922 and 1941–42.

winter and spring gave place gradually to a growth of Myxophyceæ composed of *Coelosphaerium Kützingianum* and *Aphanizomenon*. In the summer there was a considerable development of Chlorophyceæ including *Tetraspora limnetica*, *Dictyosphaerium pulchellum* and *Volvox aureus* in contrast to *Eudorina* and *Sphaerocystis* in Rostherne. *Volvox* is often associated with some pollution and the presence also of *Dinobryon divergens* and *Mallomonas sp.* would seem to indicate a high content of organic matter. The presence in both Rostherne and Hatchmere of *Botryococcus Braunii* is no doubt connected with the peaty influence, but it is not at present clear why the desmid *Closterium aciculare var sub-pronum* is confined to Rostherne and the diatom *Rhizosolenia morsa* to Hatchmere.

Budworth Mere.

The plankton collections in 1941–42 were remarkable for the abundance of a single constituent at each season. In August, the diatom *Melosira granulata* formed ninety-two per cent. of the whole; in December it was still present but the desmid *Closterium gracile* was the dominant species (seventy-six per cent.). In spring *Asterionella* was very abundant and in June *Chlamydomonas*. In 1943, *Melosira* and *Synedra* replaced *Asterionella* in the spring and *Aphanizomenon* and *Coelosphaerium Nägelianum* composed fifty-three per cent. of the autumn plankton.

Redesmere.

Redesmere is predominantly a Myxophyceæ lake, the chief constituent being *Microcystis aeruginosa*, partially replaced by *Aphanizomenon* in the summer. In 1922–42, probably owing to the competition of the Myxophyceæ the percentage of *Asterionella* never exceeded seventeen per cent., but in 1943 the spring and summer collections were more normal, showing seventy-eight per cent. of diatoms in the spring with five per cent. of Myxophyceæ and fifty-five per cent. of Myxophyceæ in the autumn. Redesmere differed from Rostherne and Hatchmere chiefly in the absence of *Ceratium* and in the prevalence of *Microcystis* rather than *Coelosphaerium* and *Aphanizomenon*.

Oakmere.

In this lake with a peaty bottom and no inflow or outlet, the plankton was composed almost entirely of *Botryococcus Braunii*.

TABLE III

	Rostherne						Hatchmere		Budworth						Redesmere		Oakmere	
	27/8/41	16/12/41	25/3/42	28/6/42	4/4/43	9/8/43	30/3/43	24/8/43	27/8/41	16/12/41	25/3/42	28/6/42	1/5/43	24/7/43	5/4/43	8/8/43	31/3/43	23/8/43
Free NH 3 ...	·24	·13	·16	·27	·04	·06	·35	·09	·48	1·76	·04	·34	·42	·16	·06	·02	·28	·07
Alb. NH 3 ...	·31	·19	·132	·48	·25	·4	·39	·76	·48	·42	09	·96	·4	·42	·32	1·0	·24	·16
Nitrate N. ...	·4	1·75	2·0	1·5	·7	·2	2·0	·2	0·0	4·0	1·8	·5	·3	·1	1·1	0·0	0·0	·2
Phosphate P2 O5	0·0	·22	·3	·05	< ·01	< ·1	< ·01	< ·1	·25	25	0 0	·3	< ·01	< ·1	< ·01	< ·1	< ·01	< ·1
Chloride Cl ...	36	28	28	32	27	27	20	20	78	61	50	92	107	107	19	19	17	18
Carbonate Ca Co3	64	70	46	68	85	90	65	85	124	100	72	82	140	140	155	190	5	5
*p*H		6·9	6·7	7·7			7·5			6 9	8 4	7·81					4	

Chemical composition of the water in relation to dissolved substances of biological importance

Ceratoneis arcus formed forty per cent. of the plankton in October, 1942, but otherwise diatoms were only occasional. Chlorophyceæ were represented by an odd individual of *Phacus* or *Pediastrum*, and the only members of the Myxophyceæ recorded were *Anabaena Lemmermannii*, fragments of which occurred in 1943, and a few colonies of *Coelosphaerium Kützingianum*. On submerged rushes near the edge was a good growth of *Spirogyra* and *Stigeoclonium*, and the copepod *Cyclops* was at times very abundant. *Botrycoccus Braunii* is characteristic of lakes with a strong peaty influence and it is significant that Blackburn records this Alga from the lake-bottom mud below the peat of Lindow Common near Wilmslow in Cheshire. (Blackburn, 1935–36.)

Chemical composition of the water.

The composition of the phytoplankton of any large body of water is known to be closely related to the quantities contained in it of certain dissolved substances of nutritive value. Table 3 shows the chemical composition of the waters of the meres under investigation in relation to these substances of biological importance. The rather great variations in the phosphate figures are probably due to the fact that different methods were used in the first four and in the last two estimations.

All the lakes except Oakmere showed features associated with heavily-silted lowland lakes surrounded by cultivated land. In these lakes there is considerable base exchange between the calcium ions associated with silt particles and the ammonia and other ions resulting from decay. They are highly calcareous, rich in available nitrogen and have high albuminoid ammonia following the decay of the very abundant summer algal population. The proximity of these lakes to the salt mining district and the suggestion that they may owe their origin to local subsidence prompted the measurement of chloride content, which proved in all cases to be high and was particularly high in Budworth. Oakmere, which derives its water from springs in the lake floor now covered with peat, was poor in dissolved salts and lacking in nitrate in the spring when it was plentiful in other lakes.

Relation between plankton and chemical composition of the water.

In Rostherne and Budworth, where quarterly analyses were made, a seasonal variation in the composition of the water was apparent. Nitrate and free ammonia were both low in autumn but rose rapidly in winter, falling off again in spring, and this fluctuation was followed closely by the diatom population. It was sometimes impossible to detect nitrate in the lake water towards the end of the summer when the available supply had been utilised by the algal growth and there had been no enrichment from decay or drainage. Albuminoid ammonia, which was relatively low in winter and spring, rose in autumn following the decay of the diatoms and Chlorophyceæ. This was usually associated with an autumnal maximum of Myxophyceæ. Carbonate and chloride were rather higher in winter than in summer.

It is not surprising that Redesmere, which showed entire depletion of nitrate in the summer and the highest autumn figure for albuminoid ammonia, was characterised by an abundance of Myxophyceæ, though it is not clear why the cosmopolitan species *Ceratium hirundinella* is nearly absent in this lake unless it be due to the lack of peaty influence or the high C/N ratio.

Budworth Mere is remarkable for its high carbonate and chloride content, the latter being five times as great as in any of the other lakes. Nitrate was high in winter but completely used up in summer, while free and albuminoid ammonia were both above the average for the lakes under consideration. The characteristic diatom was *Melosira granulata*, and *Closterium gracile* was an unusual feature of the winter plankton. Little information is available as to the plankton of lakes of high chloride content, but it would appear that this character may well encourage the growth of certian Algæ to the exclusion of others by competition. Griffiths (1925–27, No. 5) attributes the greater quantities of *Melosira granulata* found in certain of the Norfolk Broads to the enrichment of the water by river water containing dissolved salts and to occasional underflooding by sea water. Pearsall, on the other hand (1932), considers *Melosira granulata* to be a diatom associated with high organic content. In Budworth, both these factors are in operation.

Botryococcus Braunii was the predominant species in the strongly acid, peaty waters of Oakmere. Poverty of salts, particularly nitrates, precluded the development of a diatom maximum, and desmids were absent. The absence of a fringe of decaying vegetation no doubt contributed to the low figure for albuminoid ammonia, which was associated with a poor development of Myxophyceæ. In the absence of nitrates, *Botryococcus* probably develops on the bottom fed by the ammonia formed at the mud surface.

Comparison with other lakes.

The only English lakes whose plankton has been at all fully investigated in relation to the chemical composition of the water are those lying in the mountainous region of the English Lake District. In contrast to these, the Cheshire lakes lie in basins in the glacial drift overlying the soft sandstone rocks of the lowland plain surrounded by agricultural land and, with the exception of Oakmere, subject to heavy silting. In the lakes of the Lake District there is to be seen a gradation from the rocky to the silted type which is associated with an increasing enrichment of the waters by carbonates, nitrate, calcium and silica and by organic matter derived from the decay of aquatic life (Pearsall, 1921.) The figures given in Table 4 show that the Cheshire lakes are very much richer in nutrient salts than any of the Lake District waters, and this is associated with a greater abundance of phytoplankton made up largely of Myxophyceæ, Diatoms and Chlorophyceæ with desmids quite inconspicuous. The lakes of Cheshire have many points of resemblance to Lough Neagh (Dakin and Latouche, 1913), which, however, is much larger. They also resemble many continental waters, particularly the smaller, shallow lakes of the lowland country of Denmark described by Wesenburg Lund (1905).

TABLE 4.

	LAKE DISTRICT	CHESHIRE MERES
Nitrate	·005 — 0·2	0·0 — 4·0
$Ca.CO_3$	0·5 — 15·7	46·0 — 190·0
$Alb.NH_3$ ...	·01 — ·08	·09 — ·96

NOTES ON INTERESTING ALGÆ.

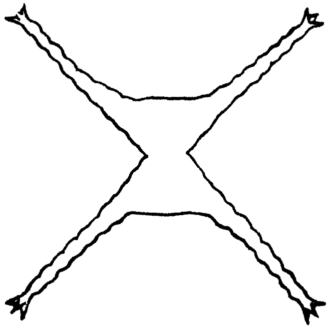
Staurastrum paradoxum. Although common in the Rostherne collections of 1914, true *Staurastrum paradoxum* no longer occurs in the meres, the nearest being a single species of the var *cingulum* in Rostherne. A small variety is, however, fairly common in all the lakes which resembles a small form of *Staurastrum paradoxum* var *longipes.* It exists in bi-radiate and tri-radiate condition and the bi-radiate form with rather longer arms is undoubtedly *Staurastrum paradoxum* var *biradiatum*, described by Griffiths from Shropshire, Cheshire and Anglesey. (Figure 1a.)

Staurastrum gracile. Two forms of *Staurastrum gracile* occur. One is the true *Staurastrum gracile* (Ralfs) about 28 μ in length, and this was found in all the meres. (Figure 1b.) The other is a much larger form, 34—40 μ in length with arms ornamented with spicules. (Figure 1, c and d.) This form was common in the earlier Rostherne collections and has also been recorded for several lakes of the English Lake District and the West of Ireland and named *St. gracile* var *planctonicum.* (Pearsall & Lind, 1945).

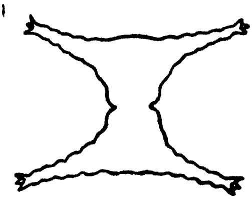
Closterium tortum. This new species is described by Griffiths (1925–27 (3)) for Marbury Mere, Cheshire. In Budworth Mere in December, 1941, the commonest organism was *Closterium gracile.* In addition there occurred what was at first described as *Closterium ceratium* because of its size and curiously contorted cell, but it lacked the acicular apices of this desmid. It now appears that this was probably *Closterium tortum* of Griffiths, but unfortunately the collection dried up before further examination could be made. The desmid resembled the *Closterium gracile*, among which it occurred in size and number of pyrenoids, but its apical regions, one or both, were curved in a direction transverse to the medium plane.

Variation in size of Asterionella colonies.

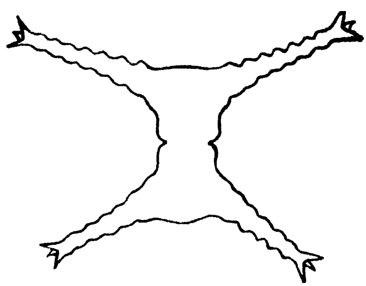
The number of cells in the colonies of *Asterionella* was seen to vary at different seasons, as did the size of the individual cells. From each collection, 50 colonies were counted and the figures given in Table 5 are percentages with various numbers of cells. The 8-celled colony was most prevalent in all waters. Colonies with more than eight cells occurred mainly in autumn and winter, and those with fewer than eight in spring and summer towards the end of the diatom maximum. The individual cells were larger in Rostherne than in other lakes.



1*a*



1*b*



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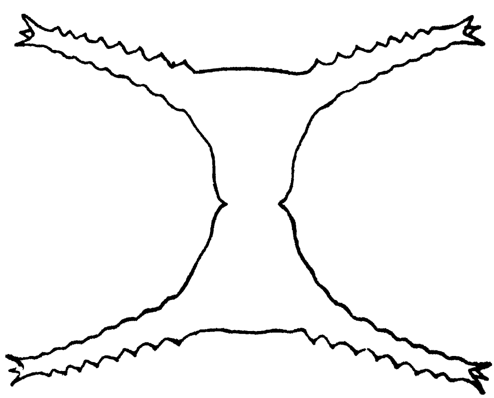

1*d*

Figure 1 *a* Staurastrum paradoxum var biradiatum. Griffiths.
b Staurastrum gracile. Ralfs.
c, d Staurastrum gracile. forma.

TABLE V.

NUMBER AND SIZE OF CELLS IN ASTERIONELLA COLONIES.

Number of cells	16	15	14	13	12	11	10	9	8	7	6	5	4	3	*Size of cell*
Rostherne 28/8/41	16	—	28	—	20	—	16	—	20	—	—	—	—	—	61μ
15/12/41	18	—	—	2	10	2	10	—	54	4	—	—	—	—	54—71μ
25/3/42	—	—	—	—	2	—	—	—	60	2	26	—	2	—	50—78μ
29/6/42	—	—	—	—	—	—	—	—	70	26	4	—	—	—	51—82μ
Hatchmere 1/10/41							Rare								
31/12/41	14	—	20	—	6	—	24	—	36	—	—	—	—	—	44—58μ
3/42	—	—	—	—	—	—	—	—	22	—	4	—	72	2	34—54μ
28/6/42	2	—	12	—	4	—	20	16	28	14	4	—	—	—	51μ

Figures represent percentage of colonies with various numbers of cells.

TABLE V—*contd.*

NUMBER AND SIZE OF CELLS IN ASTERIONELLA COLONIES.

Number of cells	16	15	14	13	12	11	10	9	8	7	6	5	4	3	*Size of cell*
Redesmere 13/9/41	—	—	—	—	—	—	—	—	54	38	6	2	—	—	34—51μ
29/1/42	2	—	2	—	4	—	2	—	88	4	—	—	—	—	38—51μ
4/4/42	—	—	—	—	—	—	—	—	22	—	4	—	72	2	34—54μ
19/7/42							Rare								
Budworth 27/8/41							Rare								
15/12/41		Collection dried up.						Mostly 4 cells.							
25/3/42	—	—	—	—	—	—	—	—	2	4	2	4	88	—	
28/6/42							Rare								

Figures represent percentage of colonies with various numbers of cells.

TABLE VI.

DISTRIBUTION OF COMMONER SPECIES.

	ROSTHERNE						HATCHMERE						REDESMERE						BUDWORTH						OAKMERE		
	28/8/41	15/12/41	25/3/42	29/6/42	5/4/43	9/8/43	1/10/41	31/12/41	15/3/42	28/6/42	31/3/43	23/8/43	13/9/41	29/1/42	4/4/42	19/7/42	4/4/43	2/8/43	27/8/41	15/12/41	25/3/42	28/6/42	1/5/43	16/7/43	7/10/42	31/3/43	23/8/43
Volvox aureus ...							2			+		4															
Eudorina elegans ...			+	50	+					+				+		+					+						
Chlamydomonas sp. ...																						85					
Scenedesmus spp. ...													4	1	10	+	2	+	2	+		3	2	+			
Dictyosphaerium pulchellum ...	+					+	4			1		6	+				+	25	+				+	+			
Pediastrum Boryanum ...	+		+		+			+			+	+	+	+	5	1	1	+	1	4	2	4	1	4			
Pediastrum duplex ...				+		+	1	+	+	2	+	+		+	+			+	+				+				+
Sphaerocystis Schroeteri ...	3																										
Tetraspora lacustris ...										10																	
Botryococcus Braunii ...	+		+	6	+	+	+	+		1	+										+				50	97	96
Staurastrum paradoxum var biradiatum	+	+			+	+	+	+	+	+		+	+		+		+	+	+	+	+	5	1	2			
Staurastrum gracile ...	+						+					+				+	+	+									
St. gracile var planctonicum ...	+	+	+	+	+	+	+	+		+	+	+	+					+									
Closterium aciculare var subpronum ...	+	1	5		+								+							+							
Closterium gracile ...																				76	+						
Asterionella formosa ...	6	66	89	+	10	6	+	98	97	15	65		17	9	5	2	53	+		6	89	+	4	20			
Melosira granulata ...					2		+	+	+	+	5	+	1			10			82	7	4	+	8	20			
Coscinodiscus lacustris ...	1	+	2		6	1					+			1	2		8		1	1			1				
Cyclotella comta ...												+							1				3	+			

TABLE VI—*contd.*

DISTRIBUTION OF COMMONER SPECIES.

	ROSTHERNE						HATCHMERE						REDESMERE						BUDWORTH						OAKMERE		
	28/8/41	15/12/41	25/3/42	29/6/42	5/4/43	9/8/43	1/10/41	31/12/41	15/3/42	28/6/42	31/3/43	23/8/43	13/9/41	29/1/42	4/4/42	19/7/42	4/4/43	2/8/43	27/8/41	15/12/41	25/3/42	28/6/42	1/5/43	16/7/43	7/10/42	31/3/43	23/8/43
Rhizosolenia morsum											7																
Synedra spp.											+				9				+				73				
Fragilaria crotoniensis							+	+		9	1[illegible]	+	+			+		2									
Fragilaria capucina			+	1	+	+			+		4		+	+		+	+		+	+	+	+					
Ceratoneis arcus																									40		
Microcystis æruginosa	1	+	+			3			+	4			62	87	67	26		37			+						
,, pulverea							1			+								+	+								
,, flos-aquae				5			1					2						1									
Aphanizomenon flos-aquae	+			2		+	64		2	1			+	+	1	57		+	+					24			
Oscillatoria spp.					+								5			+	3		2								
Coelosphærium Kützingianum	1	32	4	+	17	5	23	+		6		80	5			+		16									1
,, Nägelianum												+						+		2			1	28			
Anabaena Lemmermanii	+			10																					5		
,, affinis							+						1			+		+									
Aphanocapsa elachista																	1						1				
,, delicatissima																		+	+					1			
Ceratium hirundinella	87	+	+	23	59	84	+		+	40	3	+	+						+	+				1			
Dinobryon divergens							+			10	+																
Peridinium cinctum									+	1		+															

Summary.

The following meres lying in the Cheshire plain are described: Rostherne, Hatchmere, Budworth, Redesmere and Oakmere.

An account is given of their phytoplankton, which is shown to be abundant and composed largely of diatoms, Myxophyceæ and Chlorophyceæ, with few desmids.

The composition of the phytoplankton follows a seasonal periodicity comparable with that of other English lakes, and this is closely related to changes in the chemical composition of the water. The Cheshire meres are shown to belong to a heavily-silted type rich in dissolved salts and organic matter.

Oakmere has a bed covered by peat and is spring fed. It differs completely from the other lakes both in its phytoplankton and in the chemical composition of its water.

In conclusion, I wish to express my thanks to Lord Egerton of Tatton, Colonel J. W. Robinson, and the Winsford Urban District Council, through whose kindness I have had access to Rostherne, Redesmere and Oakmere respectively. I am also indebted to Professor Maitland and the staff of the Manchester Public Health Laboratory for the later chemical analyses, to the University Department of Agricultural Chemistry for facilities for the earlier analyses, and to Professor C. W. Wardlaw, of the Department of Cryptogamic Botany of Manchester University, in whose laboratories the work was carried out.

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Science, The Universities, and the Modern Crisis

Contributions to Two Discussion Meetings.

Science and the Modern Crisis.

MICHAEL POLANYI.

History will view, I believe, the events which have taken place on the Continent during the last generation as one coherent process of upheaval. The rise of a totalitarian regime in Russia and the growth of Fascism in other European countries will be seen to arise from joint sources. These movements will then represent together the breakdown of a previous system of public life and its replacement by a new one.

The form of European civilisation which was submerged by the European upheaval still stands out clearly in the living memory of those who like myself came to maturity before the last war It was a liberal civilisation in which free institutions had been established throughout Europe and were still being actively developed in many places. Even in the most oppressed parts of the Continent, as under Czarist Russia, liberal development had been continuously going on throughout the nineteenth century and had already achieved considerable success. To take one feature only, we may recall the activities of the Russian Duma, a kind of parliament which existed during the last 11 years before the outbreak of the Revolution. Through most of this time the Duma was dominated by parties which were sharply opposed to the existing autocratic form of government. The Marxist Social Democratic party for example, which had been formed already 30 years earlier, was represented by a considerable number of members. And though constitutionally powerless, the Duma did actually exercise political influence and even succeeded in overthrowing a number of governments to which it objected.

The degree of freedom and tolerance which were generally taken for granted in Europe before the European upheaval is almost inconceivable to the present generation. Suffice to say that the very conception of totalitarianism was unknown—except as a matter of speculation—before 1917 in Europe. No secular authority had ever even remotely attempted to enforce among its citizens a conformity of views such as is now commonly demanded in totalitarian countries.

Apart from its intolerance, modern totalitarianism exhibits as its characteristic a new hard-headed materialist conception of politics. Both Marxism and Fascism conceive of public affairs in terms of force and force alone and express sweeping contempt for the ideals which nineteenth century politicians have pursued or have professed to pursue. And as a further characteristic we find—rather paradoxically combined with this hard-headed realism—a new fanaticism, unknown to Europe in the liberal era. Thus Intolerance, Realism and Fanaticism produce together that harsh and sombre uniformity which has come to replace in many parts of Europe the more easy and varied affairs of the nineteenth century.

Naturally, we must never forget the sharp differences between the two strains of the European upheaval; the Marxist Revolution, which pursues, or has pursued for most of the time, universalistic aims intended to benefit all mankind, and the Fascist movements which set themselves the limited purpose of aggrandising one nation at the expense of others. But in spite of this distinction we may regard the joint European upheaval and the tendency of its common ideas to spread further, as constituting the crisis of our times.

Some writers would explain this crisis by a partial breakdown of capitalism. But this supposition is clearly unsound as it fails to explain why the Marxist Revolution broke out in a country in which industrial Capitalism had hardly developed at all. Other interpretations of the European crisis are based on spiritual or, generally, mental grounds, and my own comments will be on this line, as my subject is to examine the part which the rise of modern scientific thought played in producing the crisis.

Historically—and I believe also logically— the origins of the modern crisis can be traced back to the very beginnings of modern civilisation as it emerged from the Middle Ages. When the power of feudal hierarchy was gradually undermined and increasingly displaced by the authority of the State, this involved an emancipation of public authority from the tutelage of the Church and the establishment of a new supreme authority based on secular foundations. The political philosophy of the time eagerly realised the problems involved in this change.

Speculations concerning the nature of the new State and the proper justification and measure of its powers were actively pursued by many thinkers The most weighty contribution to this discussion was made by the English philosopher Thomas Hobbes in his book entitled *Leviathan* published in 1651; which did in fact provide an early formation of the totalitarian doctrine

Hobbes was profoundly affected by the teachings of Galileo, according to which the visible universe consists of matter in motion and he thus became the father of scientific materialism. As a pioneer of materialism, he was particularly suited to develop to its utmost logical implications the conception of a State based on purely secular foundations He started to develop this conception from the assumption that the State itself was subject to no obligations of any kind, that it was in fact absolute master of its own destiny Next he demanded that the State, if properly constituted, should be in a position to avert civil war between its citizens That it should have power to keep the peace in all emergencies within its realm From this he derived further the momentous conclusion—famous in the history of political thought—that all ultimate power must be vested at one single point of the State Any division of ultimate power—he argued - would leave open the possibility of a conflict between its parts, and since, by assumption, there would exist no authority superior to both parties, such conflict would represent a state of actual, or at least latent, civil war. Hence —he said— no division of powers is permissible The logic of this argument seems in fact irrefutable If the State radically refuses to acknowledge any higher power over itself, then it must be invested with absolute powers over all its subjects A Sovereign must then be free of any obligation to respect the law and be entitled to override equally any objections raised in the name of religion and morality, and even any claims of plain truth. The principle must then be accepted that the Sovereign can do no wrong.

Like his modern totalitarian successors, Hobbes reassures his audience that the absolute powers of the State would be all to the good. An absolute ruler (he maintained) is so identified with his subjects that he cannot but desire their

welfare; and in any case there can be no welfare for them outside their dependence on the Sovereign. By the same reasoning Hobbes disposed of any claims of religion, morality and science which might get into conflict with the Sovereign's decisions. He argued that no statement could be true if its contents ran contrary to the welfare of the State, as represented by the Sovereign. Thus he anticipated the most modern form of totalitarian theory, according to which the test of truth lies in its usefulness to society, the interests of which are properly represented by the authority of the State.

However, all these extraordinary teachings of Hobbes pretty well remained on paper, at least so far as English political life at Hobbes' time was concerned. Hobbes' logic was impeccable, but his assumptions were not fulfilled in reality. There *were* superior powers in existence at the time, and very effective powers at that, to which any sovereign ruler of England had to defer. The Bible was one such power. The seventeenth century was filled with religious fervour which had to be respected by the State. In these circumstances the position assigned by Hobbes to religion under the State was mere bookish speculation unrelated to the realities governing men's minds. So long as religion and the great human ideals of justice, morality and truth—which at the time were so closely related to religion—continued to be respected in their own right, the totalitarian logic of Hobbes could take no effect.

The power exercised in the public affairs of England by religious beliefs and by human ideals was actually growing stronger in Hobbes' time. A great Protestant and humanitarian movement was in the ascendant and was taking over the guidance of political progress in England for centuries to come. This movement was in fact to develop those institutions of tolerance and self-government which eventually were to spread from England to America, as well as to France and other parts of the Continent, and formed, in the nineteenth century, the foundations of the great liberal civilisation of that time.

However, in spite of the progress of these events the logic of Hobbes presently got a chance to assert itself in France through the decline of religious beliefs in that country. The rise of modern science had given birth to French Rationalism.

Under Voltaire's leadership French Enlightenment had rebelled against religious doctrine. Agnosticism or deism was becoming generally accepted among educated and progressive people all over Europe. The collapse of religious beliefs had led to the release of new humanitarian aspirations of a purely secular kind. These new aspirations were rousing demands for political reform. They were swelling the tide of resentment against the ruling semi-feudal system and fermenting the political unrest which was to culminate in the great French Revolution.

Great hopes which had hitherto found expression in religion were thus for the first time attached to the outcome of politics. The political philosophy which presided over this transformation was that of Rousseau, in whose mind the logic of Hobbes had become active and operative in a novel fashion. Rousseau agreed with every word that Hobbes had said about the Sovereign—he reaffirmed that the Sovereign must be absolute and can do no wrong—but to this he added a formidable reservation. He declared that a ruler was truly Sovereign only if his power was held justly and not by usurpation. The people were the true Sovereign ; and power was just only if it emanated from the people. Rulers who did not represent the people were usurpers, betrayers of the nation whom they were keeping enchained against their will. Thus the doctrine of Jacobinism was foreshadowed , the doctrine—as Lord Acton worded it—" That a government truly representing the people could do no wrong ". We know how this doctrine led to the first attempt at social salvation by tyranny in Europe ; to the first regime of political terror, and to the first big political purges. How each Jacobin patriot, believing himself to be the true representative of the nation, felt justified in exterminating his political opponents and rivals as traitors to the people.

However, Jacobinism was a premature attempt at the application of Hobbesian doctrine in European politics. The decay of religious beliefs was not in itself enough to open the way for the operation of the totalitarian logic. Totalitarianism cannot be established safely so long as the ideals of justice, humanity and truth continue to be respected, as they still were in the days of the Jacobins. In vain did the Jacobins quote Rousseau in support of their actions. Massacres, such as they had

perpetrated, were not yet excused at that time as necessary precautions against a potential fifth column. Their aspect roused a wave of revulsion through the world and estranged the warmest friends of the Revolution. In France itself the Jacobin terror collapsed in a few months under the burden of its crimes. The moral standards of humanity were still on guard against the advance of the Hobbesian Leviathan, even in its new popular revolutionary guise.

In the course of the nineteenth century the humanitarian ideals which had sought outlet in the French Revolution went on spreading peacefully and gradually transformed the whole Western civilisation to their image. Thus was the great liberal era inaugurated which went on flourishing until the outbreak of the present European crisis. But the axe had been laid to the tree of Liberalism from the very beginning of the nineteenth century. On the Continent of Europe scientific materialism was vigorously advancing once more. Having destroyed religious beliefs among the leaders of progress, materialism was now beginning to undermine their belief in the reality of human ideals. A new, entirely naturalistic, conception of man and of human society was becoming generally accepted by the progressive intelligentsia on the Continent.

The movement was strongest in the central and eastern parts of the Continent, particularly in Germany and Russia. It was in Russia that the figure of the modern Nihilist made its first appearance. Turgeniev described him in the person of Bazarov, hero of his novel " Fathers and Children " which was published in 1862. Bazarov denies the reality of all human ideals—even of love—and professes that man is nothing but a bundle of appetites. Turgeniev was attacked by the Russian radicals at the time, but he upheld his hero as a true portrait of the Russian intellectual and declared that he himself subscribed to the views expressed by Bazarov.

The new materialist doctrine had come to Russia mainly from Germany, where it had been spread by the writings of Büchner, Voigt and Moleschott. Büchner's famous " Kraft und Stoff " published in 1855 is represented as the bible of the young generation in Turgeniev's " Fathers and Children ". A characteristic phrase of Büchner was : " Ohne Phosphor kein

Gedanke" ("Without phosphorus no human thought") And no less men than Feuerbach and Karl Marx echoed this outlook by the pronouncement "Der Mensch ist was er isst" ("Man is what he eats")

Marx was imbued with this form of materialism, much more even than his doctrine directly expresses it His biographer, I Berlin, tells us how the manuscripts of the numerous manifestos and programmes of action to which Marx appended his name still bear the strokes of the pen and the fierce marginal comments with which he obliterated all reference to eternal justice, to the equality of man the rights of individuals or nations, to the liberty of conscience, to the fight for civilisation, and other such phrases of the democratic movements of his time -as he looked on all these as so much worthless cant indicating confusion of thought and ineffectiveness of action

Yet it would be wrong to assume that Marx became the founder of modern totalitarianism simply by delivering Hobbes' Leviathan from any moral opposition such as had caused the fall of Jacobinism

To understand the position we must realise that Marx—in spite of his denial of morality as an independent force—was passionately dominated by moral motives Even while he was angrily crossing out in his manifestos all references to social justice and human sympathy, he was burning with those very sentiments and rousing their fire everywhere among his followers Moral sentiments were not killed by Marx when he deprived them of independent standing—but only driven underground. They were compelled henceforth to operate in the dark, as the force behind the scenes of the Marxist movement

I must expand this point a little further since it is essential to the understanding of the European upheaval Marx claimed to have transformed Socialism from a Utopia into a science What he did was to provide a generation which was filled with humanitarian aspirations, but denied moral ideals, with a possibility to follow their aspirations without openly professing any ideals Marx achieved this curious feat by his supposed discovery of certain "laws of motion" in society which in his view would inevitably hoist the proletariat into supreme power. He thus offered a form of social salvation which required for

its fulfilment nothing but the action of ordinary greed and of craving for power. "Der Mensch ist was er isst" he said—but if man only keeps following his quest for food hard enough and biting sharply anyone who would deprive him of his food, he would achieve the final victory of justice. By sheer eating and biting he would establish the classless society, which is in effect a state of social perfection. Those who desired justice on earth had only to help to foment the hatred of the proletarians against the capitalists and to make sure that they would strike pitilessly when the time came to establish their dictatorship. Those adhering to this doctrine had to believe in nothing but science and the force of human appetites; and yet they could satisfy all their cravings for social justice. Such a doctrine had an irresistible attraction for the Bazarovs whose hearts were bursting with feelings to which their scepticism denied real existence.

Here I believe lies the origin of modern fanaticism, so paradoxically combined with modern realism. Modern fanaticism represents the force of suppressed moral aspirations, driven underground, and giving their blind support to a supposed scientific theory which promises social salvation by the mere force of greed and violence. When our intellect convinces us, backed by the authority of science, that our morality is worthless, and teaches us that we can achieve everything to which morality aspires, merely by letting loose our animal instincts—then our morality is converted into scientific ruthlessness. That is the picture of the modern fanatic, of the modern party man; aloof, and supremely confident of possessing a superior knowledge of reality; cruel and unscrupulous; steadfast under torture and in face of death.

Thus it appears that Marxism not merely makes the operation of totalitarian logic secure, but also endows Leviathan with revolutionary powers more fierce even than those which it possessed in its Jacobin form. Marxist materialism enables the supreme secular power postulated by Hobbes to be established in its perfect form. All religion, morality, in fact all forms of human consciousness having lost their independent standing, there is no higher power left to which the State would have to defer. Leviathan thus attains logical perfection. But

in addition, Marxism endows Leviathan with the assurance of science and the appetites of the masses, and inflames the monster with a fanaticism, distilled from the highest aspirations of mankind.

I can now deal briefly with the Fascist movements of our time Fascist doctrines are constructed on the same plan as Marxism but they differ from the latter in their moral content The primary motive incorporated in Fascism is a sentiment of patriotism This is much narrower aspiration than the desire for universal justice which underlies Marxism, but it is yet of high moral order, true patriotism includes a sense of national obligation and of national honour

But Fascism divests patriotism of its humane and honourable attributes Fascist doctrine, and the Nazi doctrine in particular — which is the most highly developed form of Fascism—transforms patriotism into a purely materialist force It converts patriotism from an ideal into a theory of violence We have here the counterpart of the transformation of Socialism by Marx "from a Utopia to a science"

It is a mistake to regard the Nazi as an untaught savage His bestiality is carefully groomed by speculations closely reflecting Marxian influence He holds a theory of national salvation by violence, based on the preponderance of the German race on the Continent, which is at least as well founded in reality as the theory of class war His contempt for humanitarian ideals has a century of materialist schooling behind it It goes back to the same origin as Marx's hatred of moral arguments– and for that matter, Nietzsche's similar hatred of morality The Nazi disbelieves in public morality in the way we disbelieve in witchcraft It is not that he has never heard of it, but that he thinks to have positive grounds to assert that such a thing cannot exist If you tell him the contrary, he will think you peculiarly old-fashioned, or simply dishonest Nor is Nazi totalitarianism based on any peculiar devotion of the German people to the State It rather represents the plain logic of all purely temporal power It is simply the Leviathan of Hobbes enthroned and made unassailable by modern scientific materialism.

Turning back, in conclusion, from the scene of the European

upheaval to the events as they developed in England since the days of Hobbes, we see now even more clearly that they belong to an altogether separate branch of European civilisation. In Britain the logic of the Leviathan has remained in suspense—not because of any magic which can prevent logic from fulfilling its implications in British public life—which is a pernicious illusion—but simply because scientific materialism was not accepted by the leaders of progress in Britain. Religion retained a dominant position in the public life of the English speaking countries and moral arguments retained their position in the guidance of public policy. Had this been otherwise or were it ever to become otherwise, the logic of Leviathan would come to be fulfilled in this country exactly as it has been fulfilled elsewhere.

I have not tried to explain why the effect which science had on the outlook of particular people was more radical than its effect on others. Why Newton's discoveries kindled a new nationalist Enlightenment in France and not in Newton's own country. Why again in the nineteenth century a new materialism was derived from science on the Continent of Europe and not in the English speaking countries; and why this materialism was implicitly accepted in the progressive circles of Germany and Russia and not to the same extent, say, in France and Holland. Having offered no views on these questions I cannot propose to discuss now the prospects of scientific materialism in Britain. But it is obvious that a new hard-headed utilitarian outlook has been spreading vigorously in the inter-war period both here and in America. If the conception of the crisis of our time which I have put forward here is even approximately correct, the fateful potentialities of such a change should be quite clear.

The Janus Heads of Knowledge.

BONAMY DOBRÉE.

Without an invitation to address you, for one who is neither a scientist nor a philosopher to enter this debate would be an impertinence. I must speak only as a victim in the modern crisis, probing here and there to endeavour to see what the situation is, and in so far as the crisis may be the result of scientific thought, as a victim of science. But as one nurtured on Huxley, retaining on his mind the enduring impress of that great moralist's *Evolution and Ethics*, particularly of the Prolegomena, I cannot but think that any totalitarian idea of brute force being the *ultima ratio* is a misinterpretation of what science has to convey.

But however this may be, there is no doubt that confusion exists, and the layman must be allowed to have his opinions about where science comes in. The confusion exists, I think, for three main reasons, which the brevity of the time to which I am entitled compels me to put too crudely. First, the ordinary man, it would appear, asks too much of science, believing that it explains the "why" of things, whereas it claims only to describe the "how," an error of great danger seeing that science now dominates general notions in the way that dogmatic religion once did. The second reason is that science does not stake its claims widely enough. Modern science so far has limited itself to being a particular way of thinking about particular kinds of things; and I would plead that it should more confidently invade other realms, and—that it should enlarge its way of thinking.

I stress the last, because the third reason for our confusion is that in the seventeenth century science took the way of thought which I shall call that of analytic perception; it excluded that other way of thinking which aims at a non-analytic grasp of wholeness, which I shall call intuitive. Mankind in the mass followed suit, so that intuition has come to be regarded merely as a rather alarming feminine attribute. It is scouted and discounted. Yet it is what the poet works with,

and no amount of analysis will make you understand Shakespeare, or Donne, or Wordsworth, certainly not Blake, just as no amount of analysis would have enabled those poets to create. Analytic perception, the way of scientific materialism, is not enough, as indeed recent scientific philosophy seems to recognise. A change in thought is beginning to be manifested, a change perhaps paralleled in the lay world. You will remember that Whitehead remarks that naturalistic art is akin to the practice of physics and chemistry, and it may well be that the breakaway of surrealistic painting, so distressing to those who regard it as working havoc in the æsthetic world, is but a sign that the painter is re-asserting his right to use the intuitive, irrational faculty, alongside the perceptive.

To go back to the second reason. To the layman it seems that science might well give greater attention to matters which at this stage may be more urgently important than the things it has hitherto investigated with such startling success, procuring dazzling triumphs in the realms of technology and in the formulation of general laws. It has, indeed, begun to turn its mind to them, and the layman calls its modern investigations "the new sciences"—psychology, anthropology, sociology. Here, since in studying them you cannot repeat experiments, nor produce exclusive laboratory conditions, analytic perception almost certainly is not enough; and one would like to suggest that science should apply itself more strenuously to these fields, using, combined with the old methods, an intuition which is different from the inspired guesses which have hitherto served it so well. It could approach æsthetics more securely, and finally encroach upon morals. Which brings me, of course, to the heart of the subject we are discussing this evening—ethics, since our crisis is, at least in part, a crisis in ethics. It is in the relation of man to man that we suffer most, and I firmly believe that science could contribute a great deal to the resolving of our crisis seen in this way. I venture to think, however, that to do so it must not rely so wholly on the analytic intellect as it has in the past three centuries, but must also use that other faculty of apprehension, that non-analytic grasp of the wholeness of an object of sense or thought which I call intuition.

This leads me to the gist of what I would like to suggest this evening, namely that what is needed in this crisis is a fusion, a synthesis, not only of knowledge but of method. Allow me to speak in university terms, since universities partly determine the direction of thought, though, luckily, their activities are to some extent guided by what goes on outside, by the pressure of opinion as to what society wants. For some generations the denizens of universities have been pursuing separate specialisations, of an increasing complexity so ramifying that specialisation has given birth to fresh specialisation. In all faculties, in all departments within the faculties, investigations are pursued without any concern for the whole, of which their work must, inescapably, form a part ; and the arts are perhaps greater sinners in this than the sciences. Yet no knowledge can, in isolation, have any meaning, any significance : any knowledge has its worth, for mankind, by virtue of its relation to something else. The final " something else " is that scale of values we are always seeking to adjust, to render more perfect in our perpetual effort to achieve a better life in terms of our changing environment, and our changing climate of opinion.

It seems to the layman, the victim, that if science is to help in solving the ethical problems of our age, it must lend itself to the creation of a synthesis of knowledge, to the pursuit, if you like, of a harmony of outlook, involving the integration of the conflicting assumptions which all of us apparently harbour. On the other hand, so must that learning which is grouped in faculties other than those of science and technology, especially in making a closer approach to the new sciences. Science, in exclusively using the analytical perceptive method, remains, naturally, in a state of innocence, knowing not good from evil : but the humanities, which necessarily use the other approach to knowledge, are largely concerned to distinguish the good from the evil. So if each must know something more than it at present usually does of the other's facts, it is just as important that each should know (and use where relevant) something of the other's proper method, and above all of the other's concepts, which arise out of, and to some degree determine, the methods and their validity.

But the practitioners on the Arts side, borne along by the compulsive current of scientific thought, have applied the method proper to scientific materialism—analytical splitting up—to matter only part of which is suitable for such an approach. The Arts side has too much neglected the other process of knowing, used it apologetically and not enough (it is regarded as " unscholarly ") and has tended to evade matter eligible for that process. It has ignored wholeness, with the result that the Arts faculties seem to be weaving their own doom, so remote are their interests gradually becoming from that humanity which is the justification for their existence. Perhaps, however, challenged by science, they can be brought back to a more active use of their appropriate method of thought.

How the sciences are to dovetail-in that method with analysis I cannot pretend to know, certainly while science, denying that morals are its business, directs its energies indifferent to the end it is pursuing. The technical difficulties would appear to be vast and baffling. Yet however that may be, the historian or the man of letters must know more about the scientist's processes (if only to be careful of their relevance to his own matter), and of what the scientist is eager to discover. For all knowledge is one if we have but the power to make it so, and the will to use that power. It is possible that the meeting ground may be the new sciences. If the moral problems which are, I hold, partly æsthetic, are to be illuminated, the man of letters must work with the psychologist ; if the political problems are to be solved, the historian must work with the anthropologist ; and so on, the more so as the frontiers between these subjects are ill-defined. There is, in fact, no frontier ; the subjects permeate each other, are indeed inter-related parts of one stupendous whole.

Both parties, I would plead, must take account of ends. Both must recognise that the proper study of mankind is man, with all that concerns him, that shapes him, that gives him his strength or marks his limitations. Both must search for that order which underlies the knowable universe, for that there is an order of some kind civilised man is convinced, even though the order may ultimately prove meaningless, as Hardy thought

it to be We believe that there is a material order, and we believe that there is a moral order, and it may be that their boundaries will fade, however different in kind the orders may now appear to be, as the boundaries between physics and chemistry have faded Even now you cannot separate apparently diverse things, politics from ethics, ethics perhaps from science, science again from art, that great integrator of thought and emotion, and it may not be digressive to note that the Greeks would not have attempted to do so

In the glorious close to *The Dunciad*, Pope, in describing chaos wrote -

> Physic from metaphysic begs defence,
> And metaphysic calls for aid on sense,

for to him, living in a society which had absorbed Descartes and Newton, such a state of affairs was bound to seem hideously confused but perhaps a situation of that kind far from being chaotic, is sane, and the condition of a state of integral consciousness At any rate it would seem that if we are to emerge from the ethical chaos which constitutes our modern crisis we must weld our analytical findings into an organic whole so that, to go back to Huxley's terms, the ethical process may triumph over the cosmic process (of which, nevertheless, it is a part) and this tortured, regressive civilisation of ours step forward into an era radically humane

Science and "The Unity of Thought"

DOROTHY M. EMMET.

Let me also begin by saying that it seems rather an impertinence to speak in this discussion when my education has been entirely on the Arts side, and I have had no scientific education (as I well believe to my great loss). I have been brought along here by the iron hand which Professor Polanyi cônceals in his velvet glove. And living as I do among scientists, I try to understand from afar off something of what they say about the nature of their various sciences. Moreover, as a philosopher I have a primary interest in the question of the relation or lack of relation between different realms of human thought and experience. I am going to confine myself to one aspect of our subject "science and the modern crisis"—namely, to the question raised by the breakdown of the unity of thought ; and can only concern myself here to-night with political and economic disruptions in so far as these may be indirectly connected with the failure to find unity in our intellectual world.

Now the unity of knowledge is supposed to be the especial interest and concern of philosophers ; and many people are asking at present why we are doing so little to achieve it. Why are there so few attempts to achieve a synthetic outlook in the grand style ? We can point perhaps only to those of Whitehead and Alexander, and these belong to the generation that is passing. When I look at my contemporaries among the younger philosophers I find them almost entirely absorbed in problems of logical and linguistic analysis, types of symbolism, and the theory of knowledge. I do not believe that this is entirely due to an unwillingness to face larger and more human issues (though to some extent no doubt it is). I believe that out of it all one question of fundamental importance is emerging—namely, how are we to determine the conditions of significant communication ? And this question is prior to any attempt at a synthesis of knowledge. For we no longer live in a common cultural civilisation with a common language (I am not referring of course to Latin, but to common presuppositions about ways of thinking and the appropriate forms in which these should be expressed). This means that the media of communication

can no longer be taken for granted. We find to-day that the pursuit of knowledge is split into departmental enquiries with different methods and presuppositions and very little attempt to clarify and relate them. In face of this, many people are saying that it is time we reversed the process and achieved a new synthesis in which science, religion, art, personal and public ethics might form an orderly pattern dominated by an agreed philosophical outlook. The blame for our failure to achieve this is being laid on "over-specialisation". But even if we were to turn ourselves into jacks of all trades and run "orientation" courses in synthetic philosophy in connection with every university department, the real problem would only be covered up. For we are at a stage when, I believe, our different worlds of thought and experience can only be made into a unity if they are dominated by some ideology. By an ideology I mean a simplification achieved by the domination of one partial type of thinking. For instance, the "scientific outlook" in art and ethics might be an ideology, no less than theological or moral dictation of what should be the results of scientific enquiry. It would be a pattern imposed on, but not growing out of the requirements of thought concerning that particular kind of experience. By "presuppositions" on the other hand I understand the assumptions which must be made in order that a particular kind of enquiry or elucidation of experience can go on at all. Now at present I believe the different kinds of thought are in for a drastic overhauling of their presuppositions; a process of which it is not yet possible to see the outcome. And while they are preoccupied with this, they may seem to be growing apart rather than growing together. We cannot yet say for certain, for instance, what are in fact the most important ideas behind the new physics, let alone what may be their relevance to a wider outlook; nor what is the real scope and contribution of psycho-analysis; nor what are the proper methods of theology and metaphysical philosophy. When we have come to the stage when Einstein, Freud, Marx, Barth, Wittgenstein, are not names for partisans to conjure with but the contributions which these may have made to our knowledge of the human mind and its relation to its world have been sifted and assimilated, then it may be time to talk about a

new synthesis. And it may be that by then we shall have found that the old style synthesis in the grand manner is impossible.

All this may sound rather depressing, and out of keeping with the spirit of this discussion. But I do not think that it need be. I am contending against any attempt to achieve unity through the imposition of an ideology. But if we resist that, what remains is the more exacting and exciting adventure of intercommunication. For this to be fruitful, we need to be able to appreciate, not the day to day results, but the methods and presuppositions of kinds of thinking other than our own specialism; the kinds of abstraction which each of us makes from man's total experience, and the kinds of mental discipline and forms of expression appropriate to each. (I believe this is more important than having a generalised smattering of the theories which may be being held for the time being in other departments of thought.)

We can also go on to ask not only what is distinctive about each kind of thinking, but whether we can discover any presuppositions common to us all. I believe we can, and in formulating them we may come near to discovering how, even if we cannot see an external unity in the pattern of knowledge, our intellectual worlds may be held together in the internal unity of certain common convictions.

1. First, I should put the conviction that these things are worth pursuing. When such an inner conviction goes into our own work, quite apart from what results or conclusions we may or may not be reaching, it can enable us to respond to a similar conviction in others, although they may be doing very different kinds of work.

2. Secondly, the importance of justice and fairmindedness in trying to appreciate what others are after. (There is a tendency in some quarters at present for people to attack by innuendo points of view they have not taken the trouble to understand.)

3. The real concern for freedom of spirit, as among the conditions which make original thought possible; and a concern, which I believe must be a conscious and open-eyed one in these days, to maintain the kind of society in which these conditions are possible.

4. The conviction that there is a real difference between genuine thought and nonsense, and that we can improve our power to recognise nonsense when we see it. This calls, I believe, for not less, but more intelligent specialisation. For those who can reach the point of doing some piece of genuine work in their own specialism are more likely to be able to appreciate genuine work in others, *provided* that they have not shut themselves away from a sympathetic awareness of the existence of other worlds of thought and experience. (Granted this important proviso, I don't think that what is said about the limitations of "transference" can be taken as a conclusive argument against this.)

5. Whatever view of the nature of man we may hold, we must ask that it must at least be one which recognises that he is the sort of being who can pursue these things—science, art, literature, religion, morality. Otherwise we saw off the branch on which we are sitting. The continental scientists of whom Professor Polanyi speaks, who taught that man is nothing but a bundle of appetites and passions, were holding a view which, if it were true, would make the pursuit of science itself impossible; which is an example of what I mean by a failure to understand one's own presuppositions.

Such common convictions may not give us a new *Summa* of knowledge, but they can give us the spirit out of which the unity of a cultural community can grow, and out of which in the long run a new synthesis (for which I believe we are not ready) may come. If I may venture a guess, I suggest that, if it were to come, it might come from philosophically minded scientists. It is more possible that they may achieve some inner appreciation of the humanities, of artistic movements, religion and poetry, than that we on our side will appreciate the important general ideas emerging from science. But it is more likely to come from a collaborative adventure in communication undertaken from both sides; remembering that it is only those who are faithful to the demands of their own discipline who are likely to have anything to communicate.

The Specialist and the Amateur.

A. D. RITCHIE.

As has been said, we are in danger of losing, if we have not lost already, the unity of our tradition; the Græco-Roman-Christian tradition that nourished the civilisation of Western Europe. I propose to deal with one single factor in that process of decay which is liable to be forgotten or misunderstood. To do this I shall start with a complaint that is often made; namely, that everybody nowadays is a specialist, that education and all occupations and professions are too highly specialised. Nowhere is specialisation more grotesque than in industry. A firm may be engaged entirely in making one component of a large-scale machine. The managing director himself does not know what it is for; he only knows the specification to which they work. The workman does not even know what the thing looks like. He only knows the single process allotted to him in drilling a $\frac{1}{4}$-in. hole in the corner of a triangular steel plate. The same disease, however, is rampant in the learned professions. There are learned men who are doing the intellectual equivalent of drilling a hole in a triangular plate and who would be most indignant if asked to drill it in a square plate.

Some people go on to say that specialisation is a modern fault. But there I differ. Specialisation can be reduced to absurdity like anything else, but it is absolutely necessary. The world's work has always been done by specialists, for the simple reason that no high-grade task, manual or mental, can be done properly except by a specialist. The poets, artists and thinkers of Ancient Greece were specialists; so were the soldiers and lawyers of Rome; so were medieval kings and churchmen, cathedral builders, painters and poets. The artists and scholars of the Renaissance were specialists; Shakespeare, Milton, Christopher Wren and Newton were specialists. And so on and so on.

An intelligent person, provided he avoids those subjects in which he is obviously deficient, can become a competent specialist in any one of a considerable range of subjects by three or four years of hard work. It is possible to be a specialist in

two subjects—your profession and your hobby—perhaps in three ; but not, I think, in four or five simultaneously. It is possible to switch over from one specialism to another by dropping the old one. But in any case nothing that needs skill and knowledge can be done well unless it has been learnt and is being continually practised : that is, unless it is done by a specialist. Therefore specialists are necessary and always will be. It is not specialisation that is wrong or new.

What is wrong and also new is that people are nothing but specialists, instead of being also amateurs of most things outside their speciality. There used to be an enlightened public of amateurs and every specialist had to appeal to them to earn recognition. Now he thinks it enough to appeal to other specialists of his own sort ; amateurs are not wanted, get snubbed if they interfere and have mostly died off. A young man with scientific ambitions works at some problem in some field of science until the half-dozen people working in that field acknowledge him as one of the gang. Nobody else need know what he is after and certainly very few care. Similarly if he wants to be a painter, poet or musical composer , provided the specialists, the other painters, etc., and the critics of painting, etc., applaud him that is all that matters. The public is not expected to understand what he is after and he prides himself on the fact that they fail to understand. In the meantime the public is satisfied with purely commercial products—things made to sell, not made because they are good or even because the maker thinks them good. So the disease spreads.

I am exaggerating because that is the only way to indicate simply and briefly a tendency not yet run to completion.

There are probably several reasons for the disappearance of the amateur. One at least is the increasing size, complexity and looseness of the modern urban aggregate of human beings —" community " one cannot call it because that is just what it is not. Improved mechanical means of " communication " have made real communication almost impossible. They enable a man to work in one place, sleep in another, rush off elsewhere in his spare time—and live nowhere. He has more and more acquaintances and fewer and fewer friends. Vast numbers can flock together and keep themselves alive by buying and selling

from each other without any other link to hold them together. My vision of Hell is of endless streets filled with hurrying crowds. Whenever you ask one of them the way, the reply is always the same : " I'm sorry, I'm a stranger here myself ".

If you go into the country south of Manchester, you will see houses and bungalows built recently by people who have done well in business, own a car, are looking forward to some leisure and wish to enjoy it in pleasant surroundings. Now compare these houses built by prosperous men of the present day to house themselves, with barns built two or three hundred years ago by farmers (far poorer men) to house their cattle. The barns are well suited to their purpose, well proportioned, of sound workmanship and blend with their surroundings. The modern houses are nearly always hideous, shoddy, inconvenient, blots on the landscape. In the past the farmer who wanted a barn got the local stonemason and joiner to do the work. They did not bother about an architect. The stonemason and joiner were specialists, but all were amateurs ; they, the farmer, the other farmers, the blacksmith, innkeeper and everybody. All knew what a barn was for, what a decent building ought to look like and what was good workmanship. If the barn was not what a barn ought to be the people passing by stared and made rude remarks. Everybody was an amateur of all that concerned local life, because everybody was a member of a community.

That community may have been petty, dull, conservative, superstitious, given to malicious gossip, filled with all seven deadly sins—say anything you like against it. It was still a community, not an aggregate ; because it was small and stable ; because everybody knew everybody else and all his business ; because most people lived and died within twenty miles of where they were born.

Ancient Athens probably was about the size of Bolton. Florence, the greatest centre of medieval and Renaissance culture, was smaller. They were communities. Manchester is not : it is too big. As for London . . . . When the late fifteenth-century poet Dunbar wrote in praise of London, calling it " flour of cities all ", it stretched along the north bank of the Thames from the Tower nearly as far as Charing Cross. The

site of Euston Station was in the depths of the country. London may then have deserved his praise. What Dunbar would say to-day would be unprintable.

I have been indicating mechanical obstacles to the existence of community which are by-products of scientific discovery. For a mechanical defect there should be a mechanical cure, if only we could find it. After the mechanical cure is found there is the harder task of recreating the community and giving it the right standards.

The Function of the University.

T. W. MANSON.

I hope that the title of this paper will not have aroused expectations that the paper itself must inevitably disappoint. Let me say at the outset that I do not intend to propound a solution to the problem which Miss Emmet stated and left unsolved at a previous meeting. Neither am I going to use this occasion to preach a sermon, though I daresay I could do that if necessary. The modest purpose of this paper is to diagnose the sickness of our civilisation and to ask what our great cultural institutions—above all the universities—can do toward healing it. So when I speak of the unity of knowledge, I certainly have in mind, though in the background, that complete and comprehensive answer to every conceivable question, which may be the unattainable goal of philosophy: the sort of knowledge that God may be supposed to enjoy, and metaphysicians to dream about. But the immediate concern is with a more modest matter: the possibility that the universities, and the kind of knowledge they acquire and impart, may be the means of restoring some measure of unity and wholeness to a disintegrating civilisation.

And with those last two words I have given my diagnosis. *Disintegration*, it seems to me, is the one word that most aptly describes the condition of mankind in these days. It is widespread and all-pervasive. Let me take a few of the more obvious examples, cases which touch our own ordinary everyday experience.

In the sphere of government we are witnessing the rapid decay of Parliamentary government. More and more the legislative functions of Parliament are being usurped by the particular Ministries, which become less and less ministries in the true meaning of that word, and more and more agencies endowed with almost absolute power. This process had already gone far before the outbreak of the present war: the war has only served to accelerate it. Most of us have some experience by now of the delays and vexations, the ever-increasing demands

and interferences which this brings to the ordinary citizen, who fills in forms and stands in queues while departments and sub-departments play badminton with his humble application.

Once upon a time, if he felt himself aggrieved or injured, he had a remedy in the courts, where there was one law administered by one justiciary. Now every government department aspires to have its own law made and administered on the premises: so that the minister is legislator, judge, and jury in any case to which he is a party; and from his decision there is no appeal.

In the social and economic sphere there is a similar breakdown. At a previous meeting Professor Ritchie pointed out the seriousness of the situation created by the decay of community life in our towns and villages, and the gradual elimination of the village craftsman. This process has been greatly accelerated by the war with its inevitable and insatiable demand for the largest quantities of equipment of all kinds produced in the shortest possible time. It has been discovered that the secret of success here is to have a strictly limited range of patterns and to " break down the job " to the utmost. Workmen no longer " make " anything. They only make " parts "—or rather tend the machines that make the parts. Others " assemble" parts made by other people in accordance with plans made by someone else. The result is a Spitfire or a landing-craft. The cathedrals of England were not made that way, nor Chippendale chairs. The danger is that more and more of our people will be condemned, in the interest of mass-production, to spend their life and energy in tasks of the most soul-destroying dullness and monotony. In " breaking-down " the job we are in danger of breaking down the men who have to do it.

There is disintegration of home and family life. The school meals, various health services, day nurseries, youth centres, communal feeding centres, to say nothing of the mass-produced syndicated entertainment provided by the Press and the Pictures —all these things cut at the family and make the home more and more a place where a small number of people have bed and breakfast. The privileges and responsibilities of parents are divided amongst various departments and carried out—so far as may be—by paid officials.

At the root of all this lies the delusion that it is the scientific way to tackle all the problems of life. Every problem can be broken up into smaller problems; every piece of work can be broken down into a number of smaller routine jobs. This business of breaking down and parcelling out the work is what is really meant by the magic word "planning"; and I am not disposed to deny that it has its uses. What I do deny is that it is the answer to *all* our problems, or even to the most important of them. Yet it continues to make great inroads: and our universities are not proof against it. Let me describe what is happening. The picture is one that will be familiar to most university teachers and students in any university.

Most discussions of the idea of a university are apt to start off in the conventional way with a classification of university functions under the conventional heads: research, teaching, solution of practical problems. Then we proceed to a nice adjustment between the claims of these different functions; and the conditions for their efficient performance. These conceptions are already too much mechanised. One hundred per cent. efficiency in performance of function is associated in the mind with the elaborate machines and complex techniques of a machine-age given over to mass-production. It has already penetrated, however, into all except the most backward departments of our universities; and it is already doing its perfect work. A great many functions—too many, perhaps—are being performed with greater or less efficiency in any university you care to name. As an example let us list the functions of the Department of Chemistry in any university:

(*a*) To get hold of the largest possible slice of capital for the erection of a palace of Chemistry (which will be declared obsolete a few years after it is opened).

(*b*) To get hold of the largest possible slice of income for the overhead charges and staffing of the palace.

(*c*) To turn out from time to time "papers" which may be understood and approved by the denizens of other palaces of Chemistry elsewhere.

(*d*) To turn out chemists: i.e.,
   (i) the future occupants of the palaces of Chemistry;
   (ii) high-grade technicians suitable for employment by government or business firms.

(iii) lower-grade chemists who will go into the schools and prepare the chemists of the next generation to enter the palace.

(iv) other chemists who must have a minimum for medical or dental purposes.

If you say "anything else?" the answer is: "Sorry; there's no time for anything else. It takes the whole three years available to work the student up to the standard required by those who will employ our graduates.

This can be applied *mutatis mutandis* elsewhere. When the department of Patagonian studies is set up the Head of the Department will naturally begin by demanding the whole time and attention of his students for the whole of their stay in the university. They will think Patagonian, talk Patagonian, breathe Patagonian, dream Patagonian o' nights. If they betray an interest in music there will be a course on Patagonian music; but not, as you might foolishly expect, in the Faculty of Music. No: in the Department. The student will enter the Patagonian Department when he matriculates: and there he will remain till he graduates.

Universitv Departments have mostly found functions—departmental ones—and carry them out with terrifying efficiency.

What is left as the function of the university?

(*a*) To act as trustee and general curator of the various departmental palaces and other quarters.

(*b*) To act as agent for the distribution of such capital sums and annual income as may be available.

(*c*) To appoint the rulers of the various palaces.

(*d*) To confer degrees on the products of the various departments.

The fact is that the university is being dismembered by the growing segregation, exclusiveness, and attempted self-sufficiency of the departments. As a cultural unit it is falling apart: the real principle of integration is the combined functions of the Registry and the Bursary, and, where a University happens to be lucky, the personal influence of the Vice-Chancellor. But these things, excellent as they are, cannot make up for the

loss of real unity in the university, cannot overcome the centrifugal tendency manifest in university life and the growing inability or disinclination of departments to encourage free communication and free interchange with one another.

The tendency will be for this dismemberment of the university to increase as universities grow and take more and more departments under their wing. How long will it be before the first university opens its doors, let us say, to the Accountants, and gives a B.Acc. as a gilt-edged guarantee that the holder knows all there is to be known about Accounting and nothing about anything else?

What I have said applies not to any one university in particular; but, I think, to all. In Oxford and Cambridge the progress of the disease is masked to some extent by the fact that the corporate life of the Colleges creates the appearance of organic unity, though I fear that it is more apparent than real.

It may as well be admitted that some departmentalisation, some breaking down of jobs, and distribution of problems is inevitable. There is a whole range of services that can best be performed by handing them over to a department specially formed to deal with the task. There are whole ranges of goods that can best be provided by mass-production methods. There is a whole range of scientific and other problems that can best be tackled by splitting them up into smaller problems and parcelling them out among the members of a research team. But it is a process that has its limits.

We might have a landscape in which the sky was done by an expert from the Meteorological Office, the trees by another from the Forestry Commission and the animals and farm buildings by a representative of the Ministry of Agriculture and Fisheries. It may be doubted whether the result would be mistaken for a Constable. And when Shakespeare wrote Hamlet he probably produced a better piece of work than could have been turned out by a committee of kings, queens, courtiers and ministers of state, though they would have had expert first-hand knowledge which he lacked. I daresay it sounds silly put in that way; but the apparent silliness covers the hard fact that there are vast areas where little or nothing can be achieved by analysis and breaking down, where synthesis

and building up are the only things that will answer. There is a kind of knowledge, and that the most important, where progress is made not by parcelling one problem out among many minds, but by bringing many problems within the grasp of one mind.

Such minds are not freaks of nature. It is as natural for man to put two and two together as it is for him to divide four into two twos. We are all capable of more than one interest and some are capable of mixing their interests on the grand scale. An example from my own field is Hugo Grotius. Most people who know of him at all know him as a very famous lawyer. He also produced three folio volumes of *Annotationes in Nouum Testamentum*, which are still in use after three hundred years, and very useful too.

What is all this leading to? Essentially a practical appeal. An appeal that the life of the individual should be an integrated whole, where unity is achieved not by scrapping every interest except one, but by bringing a variety of interests under one hat. That no graduate should ever leave a university with a profound knowledge of his own subject and a profound ignorance of every other subject in the curriculum. That workers in different fields of research should make it their business to find ways of communicating with one another; that without relaxing their own efforts in their own spheres they should be eager to know what is going on elsewhere. True the cobbler must stick to his last. " He who would accomplish anything must limit himself." *The* job of the musicians is to get on with their music, of painters and poets to get on with their painting and poetry, of scientists to get on with their science, historians with their history, theologians with their theology, in the faith that each is a way of apprehending Reality and that in the end they do harmonise. But there is a great need to look over the wall and try to understand what is going on in fields not our own.

In this way we may, I think, find a deep unity in our experience— though we may never be able to put it into an exact form of words—and achieve a real wholeness of life—though we may never be able to reduce it to a plan. And having achieved this integration, to be able and ready and willing to point others into the way of it is perhaps an aim neither despicable nor impossible of attainment.

"Subjects" in Adult Education.

R. D. WALLER.

It is one of the ironies of the history of culture that Francis Bacon, who declared all knowledge to be his province, should have presided over the process of its disintegration. He would hardly have made the statement if he had not been uneasily aware that to cover all the branches of knowledge was at last becoming impossible for most men, perhaps even for him. At any rate what he actually achieved was an admirable understanding of the *relationship* of the various parts of knowledge. Reborn, he would have Professor Manson's approval; and would make a wonderful Director of Extra-Mural Studies, for nobody needs that kind of understanding more.

He might also usefully undertake to write a new *Advancement of Learning*, a stocktaking and summary of the state of knowledge in this age. Has anybody undertaken anything of the kind? Would anybody nowadays feel competent to do it? Whoever should attempt it would feel acutely, as Bacon did not, the lack of fundamental unifying principles as a basis of order and relationship in the maze of modern research. Does not the underlying reason for the disintegration Professor Manson and others deplore in our universities, lie in the fact that they no longer know where they are going, no longer agree about any ultimate purpose? Is this the fault of scholarship, oı a malady the scholars share with the rest of the western world? Or if the latter, have the scholars still some responsibility?—if it is not their business to set a course, are they not jointly responsible at least for keeping the ship's compass in order? And are they doing so? Professor Manson clearly thinks not; and I am much inclined to agree with him.

The results of the present situation in the universities is felt acutely in the field of adult education, where you may see too often that the blinkered are leading the blind. I am thinking of the central area of the field, where adult education really attempts to be educational. Around that centre are disposed all sorts of practical pursuits, excellent and desirable and not relevant to the present point—people are learning to be plumbers, typists, accountants, learning languages and acquiring all sorts of proficiencies which they expect to have a cash value

But in the centre are thousands of people, many of them highly intelligent, whose minds are full of questions and bewilderment, people who are not looking for profit and advantage, but simply for understanding. They enter through many different gateways (called " subjects ") but really they nearly all want to know the same things :—What is the good life ?—and what sort of society is favourable to it ? What is happiness ?—is it to be pursued, and how ? Why do the nations so furiously rage together ?—and what chance is there of getting them not to ? What is freedom, and what is its relation to planning and state control ? What indeed is *man* ?—" a thing of cells and salt " ? or something a little lower than the angels ? or a bundle of conditioned reflexes ? Has he any moral responsibility ?—or is he the helpless creature of a rigid modern predestination made up of heredity and environment ? etc., etc. You all know exactly what these questions are, for they are the questions you ask yourselves and answer according to your lights.

Now it hardly matters what the " subject " may be, I have heard all these questions arising in classes of every kind—during discussions after lectures on literature, local government, political thought, international relations, philosophy, psychology, economics, geography, biology. Of course they are bound to arise—nobody can make any sense of life at all without coming to some sort of conclusion about such matters. Yet these questions commonly get very dusty answers. It is not our business to provide dogmatic replies to them ; quite the contrary ; but we ought really to be able to put every such question into a reasonable human context. The questioners don't want *ex parte* statements—they want light, intellectual light. Do we give it them ?

In the main I feel we are in the bad sense academic (in the right and good sense, academic is just what we ought to be). We are trained to have such an exact idea of the limitations of our subject ! The biologist says : " None of that—I am a scientist, and concerned only with facts ; it's no use asking me such questions." The psychologist says he's a scientist too, and that if you want to know about moral responsibility you had better go to church. The exponent of literature says he is

concerned with the study of words and expression, the excellence of plays and poems is quite independent of all such matters—he refuses to say anything about them for fear someone should say he is setting up to be a philosopher or something else which he *isn't*. And so on. Because of course, whatever light the modern world can throw on such problems needs to come from all sides at once—a single spotlight from the wings is useless, yet that is all we are encouraged to have.

This state of things probably accounts for the steadily growing popularity in adult education of the portmanteau subjects of anthropology or sociology which are everything at once, and require a new Bacon for their expositor. In such studies some approach to a satisfactory synthesis might perhaps be made, if their practitioners weren't usually so thoroughly chilled by the scientific spirit; what they serve up is often a melancholy kind of cold hash--the *disjecta membra* of European civilisation displayed on ice.

The effects of academic specialisation thus show themselves with special clarity in adult education, where they are specially unfortunate. Students in universities have at least *some* general educational grounding to fortify their minds and spirits—they bring it from their secondary schools and within the limits of their university faculties they get some breadth of view from subsidiary subjects. Adult audiences usually have no such advantages and consequently much work done in this field is really wasted and can bear no fruit; it may even be harmful, encouraging one-sided views of complicated matters or producing a sense of frustration. We are always taking too much for granted and nimbly avoiding cruxes. When we come to cross-roads where we might get a good general idea of the lie of the land, we hasten across to get into our own single high-banked lane again. We do not concentrate, or persuade our audiences to concentrate, nearly enough on the central subjects—which should be history, literature, philosophy—subjects which deal with the human record, with man's dealings with his environment, the actual relations of men and women, their desires and their actions, with the communities in which they have lived—whether as recorded by the historian or interpreted by the poets, thinkers, and artists of all ages. All this is the

substance of humane culture—and no subject at all ought really to be taught in adult education except by those who are well grounded in such matters.

People quite naturally suppose that those of us who are set aside from the bustle of the market-place to think and study, will have some light to throw onto the surrounding darkness; they suppose, and rightly, that the best intelligences of the community go into the universities and they still look to the universities with respect and confidence for guidance. They will eventually cease to do so if those best intelligences continue to be occupied in finding out who was Keats's next-door neighbour when he lived in Hampstead, or whether Lessing had or had not read some English play which certainly nobody else will ever read, so worthless is it, or how many times the word *green* appears in Middle Ruritanian texts.

I may be accused of exaggeration, but what is it then which causes so many university teachers to feel they have nothing at all to say to the man in the street, or if they do speak to him, why do they have such difficulty in finding common ground? Is there not always a vast common ground in the history, art and wisdom of centuries, of which we are or ought to be the custodians?

Confucius is reported to have said: "Am I a wise man? I do not know; but if some simple country fellow asks me a question I always go into it thoroughly with him from every point of view". What a man for adult education! But then he lived even longer ago than Bacon!

How long has the present situation existed? I suspect that to some extent it may be part of our Renascence inheritance. Browning's Grammarian has been busy settling Hoti's business for some centuries! But a subsidiary part, for our main inheritance from the Renascence is surely our humanism, whether Christian or secular. I suspect the situation has changed for the worse noticeably within the last thirty or forty years, and that the reasons for it are much too complicated to deal with in fifteen minutes.

Very few members of University Senates are now prepared on occasion to go forth and speak to the people. More and more of that work is done, but less and less of it by distinguished

scholars. It is not commonly realised how much used to be done by such gentlemen. In 1892–3 Victoria University conducted eighty-six Extension Courses, all given by members of its staff. Tout was secretary of the organising committee in 1894. A list of 1907 contains the names of Alexander, Campagnac, R. H. Case, S. J. Chapman, Oliver Elton, F. W. Moorman, Ramsay Muir, T. F. Tout, Phillip Hartog, H. B. Dixon, F. E. Weiss, Boyd Dawkins, A. E. Wilkins. You would not say from the reputation of these men and the work they have left behind them, that their scholarship was inexact or superficial. They were academic in any good sense but they found some bridge or link with the world of ordinary men. They were nearer to Confucius by half a century—perhaps that's the reason. Now we need them more—but where are their counterparts?

You will notice in that list the names of some well-known scientists. The fact is that of the eighty-six courses arranged in 1892–3, no less than fifty-six were on scientific subjects. Some of you will probably remember personally that in the heyday of University Extension scientific lectures were much in demand—much more so than they are now. That was partly because in those days there were no Technical Colleges, nor secondary schools with laboratories. But partly it was because in the 1890's, Science was Queen and was expected to reign for ever in increasing glory. The present is of course a much more scientific age. The Queen still reigns, but her subjects nowadays either take her entirely for granted without excitement (and without misgiving), or are full of dangerous thoughts and questioning her right to the throne. The young technicians, so important in any modern community, are not much interested in adult education. They are often very interested in politics, taking what they call a scientific view of such matters and holding in contempt all those studies which might offer some possibility of understanding them. For them, as for Henry Ford, history is quite commonly ***bunk***. The people who *do* come into adult education are usually concerned with fundamental problems. They bring with them a confused apparatus of pseudo-scientific notions which bother them greatly, but they don't come to study the sciences at all —or very little.

In my belief the universities would themselves gain greatly if more members of their staffs, in all departments, would throw themselves into the task of helping intelligent members of the general public to find a path through the waste land. In attempting it they would be forced to realise the relevance or irrelevance of their own knowledge to the common problems of men and women in this age. Nothing would be more likely to humanise the scientists, or to invigorate the humanities. " Research " might fall into a reasonable perspective and become more fruitful, " teaching " would improve under the acid test (i.e. adult education audiences disappear if you don't say something worth hearing) ; and partnership in a common enterprise of real human significance might bring the departments out of their intellectual isolation.

In so brief a summary many qualifications and conflicting factors have had to be disregarded, but if they were all stated, the serious proposition would remain—by seriously and corporately undertaking to make our Extra-Mural services a *People's University* we might restore in our centres of higher learning some sense of the unity of knowledge and create for the benefit of all concerned a new *Idea of a University* valid for the modern age.

The Inspiration of Eddington.

G. A. SUTHERLAND.

In the gloomy situation depicted by Professor Manson, as well as in the catastrophic one that formed the subject of Professor Polanyi's paper last November, entitled "Science and the Modern Crisis", there is a tendency on the part of those whose interests are in the "humanities" to regard the scientific man as essentially the villain of the piece. But responsibility for the present state of affairs cannot be so easily disclaimed by one group of thinkers and concentrated on the shoulders of another. In fact it should be widely distributed. The departmentalisation of knowledge is not the exclusive work of the scientist.

The material successes of science have been spectacular. But the spectacle has appealed not only to men of science: it has been acclaimed by all If the scientists have had their heads turned, that is due not solely to the sense of achievement their individual successes in a limited field have brought, but to the almost universal hailing of the progress of science as something indisputably making for the good of mankind. And although every intelligent man must realise that the same scientific progress brings within our reach comfortable houses and bombing planes, cures for diseases and poison gases, machines to eliminate drudgery and flying bombs, yet for long only lone voices were found to point the moral that science was ethically colourless; the majority of people have been gulled into the astonishing belief that somehow Science with a capital S will take the place religion occupied in the past.

The belated realisation that science *is* ethically colourless and promotes good or evil indifferently has in most quarters produced effects no less astonishing. On the one hand many scientists have claimed that because good and evil are outside the field of science therefore the scientist has in effect no concern with the uses to which his discoveries are put—an attitude now being combated by groups exercised about the social implications of science. On the other hand philosophers and theologians have tended to welcome the accepted ethical neutrality of science as a justification for a refusal to take any

cognisance of scientific discovery, as something unrelated to truth as their compartment conceives it. The results are disastrous. What should promote unity of knowledge has often departmentalised it, what should unite men has divided them. We need a recovery of the sense of the common cause of mankind which in times past religion took for granted in theory, however imperfectly it may have implemented it in practice. Ethics may not be within the field that science investigates; yet it is an ethical value that is behind the whole spirit of scientific research and for that alone ethics are a prime concern of scientists as scientists, leaving out the consideration that the scientist is also a human being. Nor does the fact that the things science investigates are incommensurable with the values of philosophy mean that they are no concern of the philosopher.

The gravamen of the charge against scientists, philosophers, theologians alike is not that they have not been content to stick to their own separate spheres but that they have gloried in their separateness and have regarded any disparity in their findings either as a proof of the futility of all studies but their own, or as a disaster, a knowledge of which must at all costs be kept from the ears of the common people lest their religious faith be shaken. In fact such disparities are opportunities for the perception of subtler aspects of truth, as science in its own sphere has proved over and over again.

Those who look to science to take the place that religion once occupied are in the case of the man who looks to the compass to lead him in the hills. So long as the rock is not magnetic the compass is an invaluable adjunct *provided that a man knows where he is and where he wishes to go.* These provisos are all important. Apart from a previous knowledge of the map the compass will not give him a jot of information as to where he is nor any advice whether the goal he seeks is worth attaining or not. Nor will it select for him a goal that is.

But a recognition that science has its limitations is a negative conclusion: indeed it should not be a conclusion at all, but merely a point of departure for new investigation. Treated as a conclusion it tends to lead to the separation rather than the synthesis of truth. Now the analytical method of dissection

on which until recently many of the most spectacular of scientific successes were based is intrinsically incomplete, and therefore ultimately unsound, unless it is accompanied by attempts at integration or synthesis. This point was picturesquely put by Eddington some years ago in a public lecture delivered in Manchester, in some such terms as these: Hitherto physical science has been content to investigate the properties of 1, assuming that because 2 is 1 and 1, therefore if you know what 1 is you know what 2 is. But this is a fallacy: you still have to find out what "and" is.

It is not accidental that it is the most brilliant minds that realise most the necessity of, and strive most for, a synthesis of knowledge and that those are most successful in the quest and in the exposition of their findings whose own life has some deep unifying principle.

Eddington was such a man. In his own phrase: "In the world seen or unseen there is place for adventure as well as for triangulation". One might add that for much of the triangulation in which minor researches consist the only justification is that the detail it reveals may assist the seer who can apprehend its significance in the adventure of synthesis he is making.

Pre-eminently Eddington sought out and ensued unity in knowledge. To him the separation of knowledge into compartments was a complication rather than a simplification. In comparing the certainty of things spiritual and things temporal he bids us not forget that "mind is the first and most direct thing in our experience; all else is remote inference". This, he points out, applies just as much to the observations in the physical world as to any other:

"Leaving out all æsthetic, ethical, or spiritual aspects of our environment", he says, "we are faced with qualities such as massiveness, substantiality, extension, duration, which are supposed to belong to the domain of physics. In a sense they do belong; but physics is not in a position to handle them directly. The essence of their nature is inscrutable; we may use mental pictures to aid calculations, but no image in the mind can be a replica of that which is not in the mind. And so in its actual procedure physics studies not these inscrutable qualities but pointer readings which we can observe. The

former have as much resemblance to the latter as a telephone number has to a subscriber. . . . Physics is now in course of abandoning all claim to a type of knowledge which it formerly asserted without hesitation. I venture to say that the division of the external world into a material world and a spiritual world is superficial, and that the deep line of cleavage is between the metrical and the non-metrical aspects of the worlds. . . . The exposure of the cycle of physical definition causes a change in our attitude which can best be illustrated by an example. The nineteenth century physicist felt that he knew just what he was dealing with when he used terms such as matter or atoms. He was ready to admit that much remained to be found out about their structure, but their general nature was definite enough. The atoms were just tiny billiard-balls—a crisp statement which was supposed to tell you about their nature in a way which could never be achieved for the transcendental entities of the world such as pain, beauty, personality, or consciousness. Chemical analysis of the brain showed that it was composed of atoms of the familiar elements occurring in inorganic nature. The unanswerable question was, by what strange means had this collection of billiard-balls acquired the property of secreting thought—a transcendental entity in no way akin to atoms. But we now see that physics has nothing to say as to the inscrutable nature of an atom ; what it studies is the linkage of atomic properties to other terms in the physicist's vocabulary, each depending on the other in endless chain with the same inscrutable nature running through the whole. *There is nothing to prevent the assemblage of atoms forming the brain from being itself a thinking-machine in virtue of that nature which physics leaves undetermined and undeterminable.* Because we see that our precise knowledge of certain aspects of the behaviour of atoms leaves their intrinsic nature just as transcendental and inscrutable as the nature of mind, so the difficulty of interaction of matter and mind is lessened. We create unnecessary difficulty for ourselves by postulating two inscrutabilities instead of one ".

One of Eddington's most valuable assets in demonstrating the unity of knowledge was the facility with which he could expound his ideas. A wide and deep acquaintance with great

literature and a keen sense of humour contributed to the happiness of his illustrations. The assimilation of new knowledge and the necessary re-thinking of fundamental ideas such as those of space and time requires a receptive and also a bold creative mind. Unfamiliarity with new ideas raises an unscalable wall between ordinary men and the truth. The difficulty about relativity, he used to say, is not to understand it but to believe it, and his expositions went far to making new ideas credible.

In this process of re-thinking, he found new evidence of the limitations of a purely material view of reality such as had been gaining ground as the hold of religion declined. He could express his convictions in terms that made the limitations apparent also to ordinary men. His eminence gave the lie to any suggestion that the only scientific men interested in spiritual values were second-raters.

But the fundamental reason for Eddington's success in unifying knowledge was, as has been said, the fact that a unifying principle underlay all his thought. The human mind was not to him an independent light but a spark from the divine mind, which enshrined the ultimate reality. The fundamental thing in his world was something intent on truth, something to which it mattered intensely that belief should be true. Responsibility towards truth was an attribute of man's nature. In other words it was through his spiritual nature, of which responsibility for truth was a typical manifestation, that man first came into the world of experience—his entry via the physical universe was a re-entry.

The process of the unification of knowledge did not to him mean accepting the ground-plan of physical science and trying to build philosophy and religion on that as a foundation. He sought to apply the inductive process in every search for truth and to attain the proper orientation of the mind to the different elements of experience. The interaction of man with his environment was what made up experience, and a man's environment was not just a physical environment. Yet, as truly as the mystic, the scientist was following a light. It was not an inferior light; on the contrary the answers given by science had a singular perfection, prized the more because of

the long record of toil and achievement behind them. But they answered only specifically scientific questions. The answers to religious and similar questions could be similarly authoritative only in so far as they too were based on an analogous inductive process.

The study of the visible universe began with a determination to use the eyes, which involved an act of faith—a belief that what the eyes had to show was significant. By an analogous determination the mystic, recognising another faculty of consciousness, accepted as significant the vista of a world outside space and time that it revealed.

Although inclined to criticise theology and philosophy for being content with what in comparison with the findings of physical science might be ranked as " vague unchecked conjectures " he modestly proceeds, " the physicist who inveighs against the lack of coherence and the indefiniteness of theological theories, will probably speak not much less harshly of the theories of biology and psychology. They also fail to come up to his standard of methodology. On the other side of him stands an even superior being—the pure mathematician—who has no high opinion of the methods of deduction used in physics, and does not hide his disapproval of the laxity of what is accepted as proof in physical science. And yet somehow knowledge grows in all these branches. Wherever a way opens we are impelled to seek by the only methods that can be devised for that particular opening, not over-rating the security of our finding, but conscious that in this activity of mind we are obeying the light that is in our nature ".

Something of the nature of Eddington's own religious inspiration and evidence that it illuminated and at the same time was illuminated by his scientific thought is indicated in the concluding paragraphs of a lecture entitled " Science and the Unseen World " he gave in London in 1929 to the Yearly Meeting of the Society of Friends.

" In its early days our Society owed much to a people who called themselves Seekers ; they joined us in great numbers and were prominent in the spread of Quakerism. It is a name which must appeal strongly to the scientific temperament. The name has died out, but I think that the spirit of seeking

is still the prevailing one in our faith, which for that reason is not embodied in any creed or formula. It is perhaps difficult sufficiently to emphasise Seeking without disparaging its correlative Finding. But I must risk this, for Finding has a clamorous voice that proclaims its own importance; it is definite and assured, something that we can take hold of—that is what we all want, or think we want. Yet how transitory it proves. The finding of one generation will not serve for the next. It tarnishes rapidly except it be preserved with an ever-renewed spirit of seeking It is the same, too, in science. How easy in a popular lecture to tell of the findings, the new discoveries which will be amended, contradicted, superseded in the next fifty years! How difficult to convey the scientific spirit of seeking which fulfils itself in this tortuous course of progress towards truth! You will understand the true spirit neither of science nor of religion unless seeking is placed in the forefront.

"Religious creeds are a great obstacle to any full sympathy between the outlook of the scientist and the outlook which religion is so often supposed to require. I recognise that the practice of a religious community cannot be regulated solely in the interests of its scientifically-minded members, and therefore I would not go so far as to urge that no kind of defence of creeds is possible. But I think it may be said that Quakerism in dispensing with creeds holds out a hand to the scientist. The scientific objection is not merely to particular creeds which assert in outworn phraseology beliefs which are either no longer held or no longer convey inspiration to life. The spirit of seeking which animates us refuses to regard any kind of creed as its goal. It would be a shock to come across a university where it was the practice of the students to recite adherence to Newton's laws of motion, to Maxwell's equations and to the electromagnetic theory of light. We should not deplore it the less if our own pet theory happened to be included, or if the list were brought up to date every few years. We should say that the students cannot possibly realise the intention of scientific training if they are taught to look on these results as things to be recited and subscribed to. Science may fall short of its ideal, and although the peril scarcely takes this extreme form, it is

not always easy, particularly in popular science, to maintain our stand against creed and dogma. I would not be sorry to borrow for our scientific pronouncements the passage prefixed to the Advices of the Society of Friends in 1656 and repeated in the current General Advices :

> " 'These things we do not lay upon you as a rule or form to walk by ; but that all with a measure of the light, which is pure and holy, may be guided ; and so in the light walking and abiding, these things may be fulfilled in the Spirit, not in the letter ; for the letter killeth, but the Spirit giveth life.'

" Rejection of creed is not inconsistent with being possessed by a living belief. We have no creed in science, but we are not lukewarm in our beliefs. The belief is not that all the knowledge of the universe that we hold so enthusiastically will survive in the letter ; but a sureness that we are on the road. If our so-called facts are changing shadows, they are shadows cast by the light of constant truth. So, too, in religion we are repelled by that confident theological doctrine which has settled for all generations just how the spiritual world is worked ; but we need not turn aside from the measure of light that comes into our experience showing us a Way through the unseen world.

" Religion for the conscientious seeker is not all a matter of doubt and self-questionings. There is a kind of sureness which is very different from cocksureness ".

Discussion.

During the discussion which followed Professor Polanyi's paper, Principal R. V. Holt pointed out that cruel fanaticism was to be found in the Middle Ages in a civilisation dominated by religion and in some of its finest souls like St. Bernard. He concluded therefore that this spirit could not be attributed primarily to a secular civilisation but rather to the fact that devotion to the new State has indeed become a new kind of religion. In his opinion fanaticism is due to dogmatism, and dogmatism is due finally to lurking fear and uncertainty. Whenever men and women try to keep their faith by identifying their vision of what they regard as the ideal with any particular embodiment of it, they tend to regard any means as justifiable to attain the desired end. This applies whether the ideal is regarded as embodied in a church or a New Order of Society, and whether it finds expression in a religious dogma or a " secular " ideology.

Comments on Professor Polanyi's paper.

By R. A. C. Oliver.

Professor Polanyi's argument, as I understand it, may be summarised as follows: European civilisation has broken down because religion and morality have been undermined by scientific materialism. There is so much in his extended argument with which I agree, and at the same time so much which I cannot wholly accept, that it will be necessary to discuss his argument in some detail.

In the first section of his argument (paragraphs 1 to 5) Professor Polanyi presents "the events which have taken place on the Continent during the last generation as one coherent process of upheaval". This view may be correct, but I do not think it can be assumed to be correct, and I do not think Professor Polanyi has proved that it is correct He refers to "the rise of a totalitarian regime in Russia and the growth of Fascism in other European countries", and appears to equate these events with the breakdown or submergence of "European civilisation" as a whole. I doubt whether this equation is justified. Professor Polanyi does not seem to claim that European civilisation has broken down or been submerged everywhere: for example in this country or in the British Dominions or in the United States. If he does not claim this, I think it is incumbent on him to show more clearly than he does why European civilisation has not universally broken down. Its survival in some parts of the world would be just as much a part of the situation he is trying to account for as its breakdown in other parts.

Perhaps, however, Professor Polanyi is only claiming that European civilisation has broken down or been submerged on the Continent of Europe. If so, I think it useful to distinguish between "breaking down" and "submergence". I should agree wholeheartedly that European civilisation has been submerged in every country which has been over-run by the Germans. But that is a different thing from its breaking down.

I should not agree that it has broken down, in the sense of decaying internally, in France, for example, or Belgium, or Holland, or Norway. There are already ample signs to the contrary. In these countries European civilisation has been temporarily submerged by military power, but it is not self-evident that it has decayed.

Professor Polanyi might argue that European civilisation in France and elsewhere was submerged by German military power because it had already decayed—that France fell in 1940, for example, because it was rotten. That is arguable; but French resistance since 1940 is as much a fact to be accounted for as the fall of France in 1940, and no explanation of events is satisfactory unless it accounts for all of them and not merely for a selection of them.

My point, then, is that Professor Polanyi's premise that European civilisation has broken down may or may not correspond with the facts, but that I do not think he has established that it does.

Professor Polanyi seems to imply another premise which I think cannot be assumed and which I think he does not establish. He seems to interpret European history before the last war in a way which in certain respects cannot be taken for granted. I think he over-estimates the degree to which European civilisation had become " a liberal civilisation in which free institutions had been established throughout Europe ". I should agree that free institutions " were still being actively developed in many places ". But in the perspective of history the development had not in some countries been a long one; free institutions had not everywhere taken deep root. They had had least time to establish themselves, perhaps, in the very countries which have adopted totalitarian forms of government—Russia, Germany, Italy, Spain. Professor Polanyi refers, for example, to " the Russian Duma, a kind of parliament which existed during the last eleven years before the outbreak of the Revolution ". This is a very short period in the history of free institutions, particularly if, as he states, the Duma was still " constitutionally powerless ".

Nor on the other hand can I accept the view Professor Polanyi seems to take of the comparative novelty in European

history of intolerance, "realism" (in Professor Polanyi's sense) and fanaticism. When I think of the Conquistadors, of Machiavelli, of the Tennessee state laws against the teaching of evolution, to name but a few instances, I fail to find a golden age, and I can only assume I have misunderstood Professor Polanyi's argument. To me it seems not that intolerance, "realism" and fanaticism have necessarily increased, but that they can now in certain circumstances enslave mind and body by the use of modern techniques of propaganda and military power.

Thus Professor Polanyi sets out to explain a present situation and a previous history which, when I view them in a wider perspective of time and place, I cannot altogether accept as premises. The explanation he attempts to give is already coloured by his interpretation of what he has to explain. A different interpretation might have led to a different explanation. Nevertheless, I should accept that European civilisation is at present in a dangerous situation.

Professor Polanyi at once rejects an explanation in terms of "a partial breakdown of Capitalism".* I agree with Professor Polanyi at any rate that the partial breakdown of capitalism is not the whole explanation of events, and that the deeper explanations are what he terms "spiritual or, generally, mental". In other words, some people in Europe behave differently nowadays because they think and feel differently. Professor Polanyi thus makes the problem a psychological one, and I agree with him. If he claims, as I think he does, that some people in Europe behave badly because they think badly and because they feel wrongly about things, I should also agree with him. When Professor Polanyi comes to apply his psychological analysis in detail, however,

* I should not disagree with him in rejecting this as the whole explanation, though in passing I may say I do not find the particular reason he gives for rejecting it wholly convincing. He considers this explanation is "clearly unsound as it fails to explain why the Marxist Revolution broke out in a country in which industrial Capitalism had hardly developed at all". I should have thought that the Marxist Revolution was imposed on a country in which industrial Capitalism had hardly developed, and which only wanted a revolution; and that the revolution took a Marxist form because the Marxists were the best-organised group of revolutionaries. But that is by the way.

his argument again requires closer examination, for it is possible to make more than one psychological analysis and thus to arrive at more than one interpretation of events.

I shall not attempt to follow in detail Professor Polanyi's exposition of the doctrines of Hobbes. There are, however, a few observations I should like to make.

First, Professor Polanyi seems to dislike (as I do) Hobbes's belief that the authority of the state, and in particular of the sovereign, should be supreme. If I follow Professor Polanyi's argument, however, his objection is not so much an objection to authoritarianism as an objection to secular authoritarianism, since he seems to date "the origins of the modern crisis" to "the emancipation of public authority from the tutelage of the Church and the establishment of a new supreme authority based on secular foundations".

Second, I cannot altogether agree with Professor Polanyi's account, if I understand it correctly, of the reasons why Hobbes's teaching had so little practical effect in his own country. Professor Polanyi suggests that Hobbes's teaching was checked by "the power exercised in the public affairs of England by religious beliefs and by human ideals", and that this power "was actually growing stronger in Hobbes's time". He goes on to suggest that a great religious and humanitarian movement was in the ascendant and was destined to develop institutions of tolerance and self-government which were eventually to spread to America, France and elsewhere. In point of fact, however, while humanitarian ideals were in the ascendant, religious fervour was declining in England towards the end of the seventeenth century and was not universally ardent in the eighteenth century. The period in which "institutions of tolerance and self-government" developed was heralded rather by such events as the constitutional revolution and the founding of the Royal Society than by the growth of religious belief. Professor Polanyi is surely more accurate when he goes on to refer to the decline of religious beliefs in France in the eighteenth century, and to "the release of new humanitarian aspirations of a purely secular kind". Yet the development of "institutions of tolerance and self-government" in America and elsewhere owed as much to the inspiration of

the French Enlightenment as to the supposed great religious and humanitarian movement which Professor Polanyi discerns as growing stronger in Hobbes's time.

Third, in his discussion of the development of Hobbes's doctrine by Rousseau, and of the relation of Rousseau's doctrine to Jacobinism and the Terror, Professor Polanyi seems to me to attempt to discredit a theory by the bad behaviour of certain people who were associated with it, whereas I do not think that the conduct of some French revolutionaries in itself proves that Rousseau or Hobbes was wrong. Professor Polanyi himself goes on to say that " in the course of the nineteenth century the humanitarian ideals which had sought outlet in the French Revolution went on spreading peacefully and gradually transformed the whole Western civilisation to their image. Thus was the great liberal era inaugurated which went on flourishing until the outbreak of the present European crisis ". Here Professor Polanyi seems to attribute the great liberal era of Western civilisation, whose passing he regrets, to the humanitarian ideals which had developed in the eighteenth-century France which he appears to condemn.

I have been discussing, perhaps with too great minuteness, what are after all but details in Professor Polanyi's argument. I shall now comment, as concisely as I can, on Professor Polanyi's general explanation of the condition of European civilisation.

Professor Polanyi argues, I think, that European civilisation rested on a foundation of religious and moral beliefs. I agree with him. I revert to Professor Polanyi's suggestion that the causes of such breakdown as has occurred are psychological. The fact we have to explain is that some people in Europe behave badly. From the psychological point of view which Professor Polanyi suggests we adopt, people behave well or ill because they hold certain beliefs about themselves, about other people and about the nature of the universe in which they live, and because they feel strongly about these things. Their actions are governed by their thoughts and feelings. In order that they should act well, they must have a set of strongly felt beliefs that will cause them to act well. Religion and morality provide such systems of strongly felt beliefs. Religion and morality have been very closely associated. In European

civilisation morality has in fact largely depended on religious belief. Professor Polanyi I think attributes the events in Europe to the fact that scientific thought has caused some people to abandon their religious beliefs and with them the traditional ethical principles on which European civilisation rests. If this is, as I think, his diagnosis, I should agree with him.

Does Professor Polanyi carry his diagnosis further? Does he attempt any prognosis? I think he does, for example in the following passage :—

" Religion retained a dominant position in the public life of the English speaking countries *and* moral arguments retained their position in the guidance of public policy. Had this been otherwise, or *were it ever to become otherwise, the logic of Leviathan* would have been, or *would be, fulfilled in this country exactly as it has been fulfilled elsewhere.*" (My italics.)

In making this prediction, Professor Polanyi asserts that both religion and morality are necessary conditions of the prevention of the breakdown of European civilisation. But this, I think, is just the point which is at issue. Certainly morality has most commonly depended on religious sanctions, but the vital question which I think no one can yet answer decisively is whether morality necessarily depends on religious sanctions. We can only examine such evidence as we have. It would, I think, be generally agreed that some people who accept religious sanctions behave in ways which Professor Polanyi and I would regard as morally bad ; many adherents of churches, for example, have supported various forms of Fascism in Europe and South America. It would also be generally agreed, I think, that some people who do not accept religious sanctions in the usual sense behave in ways which Professor Polanyi and I would regard as morally good ; thus it is widely asserted by leaders of the churches in this country that a large proportion, even a majority, of the people of this country have ceased to profess religious belief, yet it would be hazardous to suggest that the demeanour of the people during the last few years or the aspirations which they hold for the post-war world betoken a deep degeneration of morality. If this evidence is accepted, we cannot, I think, assert that there can be no morality without religious sanctions, and the outlook for the

future is then not necessarily such as Professor Polanyi predicts. It may on the contrary prove that the ethical foundations of European civilisation, maintained alike by those who regard religious sanctions as essential and by those who do not, will stand secure. We may be living in a period of crisis because we do not yet know whether morals can survive among the mass of the people without the religious belief which so many of them seem to have abandoned. I do not think we can yet foresee how the crisis will be resolved. It may be that science and religion will again be reconciled in the minds of those who have abandoned religion and that thus moral principles may be re-established with the sanctions both of human experience and of belief in superhuman law. Certainly there is no deep cleavage in ethical principles between many of those who accept religious sanctions and many of those who do not. It does seem clear, however, that we cannot hope to effect such a reconcilement by giving up the quest for scientific truth. Nor, I think, can we conceal the results of our quest from people in general, or distort these results for them, as Plato would have done and as the Fascists do. We must be prepared to endure a period of uneasiness or even of crisis, for like Donne in the seventeenth century, we live in a period when "the new philosophy throws all in doubt". We could at present achieve unity of belief only through the imposition of an ideology, and like Miss Emmet, I should prefer "the more exacting and exciting adventure" of the further search for truth. I find encouragement in the presuppositions which her ripe philosophical judgment discerns as holding our intellectual worlds together—the conviction that truth is worth pursuing, the importance of justice and fairmindedness, respect for freedom of spirit, the conviction that we can to some extent recognise nonsense when we see it, and the recognition that man can interpret experience in more than one way. These presuppositions, which I agree are common to a great many people in European civilisation, may not provide the unity of an ideology, but they constitute a not altogether unsatisfactory ground on which European civilisation may continue to grow.

K

Some Observations on Professor Manson's paper.

By S. Hird.

It seems to me that the disintegration of knowledge which Professor Manson deplores is no new thing at the University. What does seem to be new is the consciousness of it. I was a student of Owens College from 1896 to 1900. In the different faculties we were in watertight compartments. We engineers had nothing in common with the medicals or the chemists. We had a little more with the physicists through our joint attendance at the mathematics classes. Once we had passed the Preliminary examination as it was then called we had nothing in common with the Arts side either. The only things we had in common were the opening lecture and the Shrove Tuesday procession, which in those days of Adolphus Ward was not considered a respectable business at all. In fact it was said officially to be a most irregular proceeding.

Then was the time when integration would have been much easier than now, for we were not physically separated in different buildings. We all occupied the same building, the old buildings as I think you call them now. Only the medicals were completely separated, and they had some contact with our side in their chemical and physics courses. We knew all the Professors by sight. It would not have been a difficult thing then to bring all the faculties together on one common cultural basis as it were, and so have established a tradition which might have held in spite of the subsequent inevitable segregation in separate buildings.

So we grew up on the science side without that wider and more general education and training which could so easily have been given to us by, say, Tout, Alexander, and others. But fortunately for me, there came round at that time to the town where I lived, under the auspices of the local Co-operative Society, an Oxford University Extension lecturer of the name of Hudson Shaw, and he lectured on History to crowded audiences of working people who, notwithstanding twelve hours' hard

work in a mill, were prepared not only to listen to a lecture but to take part in a study class. He made history live, and to this day I meet old working men who remember him with gratitude. At any rate he gave to me what the Owens College and the Victoria University did not give. But the past is past and cannot be recalled or amended. What can be done now?

I suggest

(1) That the opening lecture of the session be revived, and as it may not be practicable to give it to all students let it at any rate be given to the freshmen, and let it be a lecture which will give them some vision of that integration and unity of knowledge of which Professor Manson spoke in his address.

(2) Let there be one course of lectures compulsory on all students which shall be a review of all branches of human knowledge and philosophy. (Incidentally the most vivid thing I remember was listening to Professor Alexander's lecture on Philosophy (on my first day at the College).

(3) The institution of a special prize for the best essay on the subject of the course.

The whole of this would need to be superlatively well done if it were to achieve its object of impressing on all students the essential idea of the unity of knowledge, and preventing that watertight compartmenting of special knowledge which deludes one into thinking that it is all right with the ship if it is all right in that compartment.

Another observation I may perhaps be permitted to make is that the monotony of certain jobs consequent on the breaking down of operations in mass production has been exaggerated, or rather its effect on the individual has erroneously been assumed to be necessarily a bad one. I say this not only from personal experience but from many years' experience as a factory inspector. The more simple the job is, the more it gets done so automatically that the mind gives very little attention to it and is free to wander on other things of more interest to itself. I am surprised this is not realised, for every one must be familiar with the spectacle of a woman knitting and of how she can be carrying on that operation whilst engaging in an animated

conversation, or reading, or listening to the wireless or to music. So it is with these monotonous jobs. The doers of them, if they are collected together, are talking to one another, or are dreaming on their own or are observing what is going on about them. Only when some turn about comes in the job, as it does when the woman knitting comes to some change and has to devote more attention to it, does the conscious mind come into action again.

The breaking down into fewer or single operations is a necessary consequence of mass production and of an ample supply of those good things of the world which we all want. If we had to wait for Chippendale chairs we should have to sit crosslegged on the floor. Besides, it does not really mean a decay in craftsmanship on the whole. It is really a shifting of the incidence of craftsmanship from one job to another. I have no doubt that in the far distant past when the plough was first introduced, the makers and users of spades deplored the introduction of the more advanced implement as likely to lead to the decline of spadesmanship. With the machine we get the designer, the draughtsman, the patternmaker, the foundryman, the machinist, the fitter and assembler, and with the use of the machine the tackler who must keep it in order, and finally the attendant or tenter of the machine. All these have their several craftsmanships. Likewise in the professions, all have specialised or broken down their various jobs in the last few years, but without loss of skill and without necessarily losing sight of the object of the profession as a whole. In the manufacture of machines or motor cars the disintegration or breaking down of jobs is only the preliminary to the more effective assembly of the whole. What we have to ensure, then, is the realisation that the disintegration of knowledge is a necessary or inevitable step to the more complete and effective unity necessary to the progress of mankind.

Postscript.

BY PROFESSOR POLANYI.

I wish Professor Oliver had limited himself to criticising what I have said rather than suggesting what other subjects he thinks I ought to have discussed. It is also unfortunate that he sometimes seems more preoccupied with my words than with their context. I can see, however, some interesting points in Professor Oliver's remarks which I should like to take up here. He says that he can see no golden age preceding the present era and mentions such instances as the Conquistadors, Machiavelli and the Tennessee State Laws against the teaching of evolution to illustrate his point that intolerance, "realism" and fanaticism have not necessarily increased but that they can now in certain circumstances enslave mind and body by the use of modern techniques of propaganda and military power. This is an important view, widely held to-day; but it is without foundation in fact. The main events which started the modern era of totalitarianism were the establishment of a Bolshevik Dictatorship in Russia (1917) and in Hungary (1919), in Bavaria (1919); then the White Terror in Hungary (1919) and the establishment of Italian Fascism in (1922). All these events took place before the invention of the radio and without the use of any modern military technique. The Bolshevik Revolution in Hungary, for example, took place practically without any armed action and in circumstances of an exceptional lack of arms among the population. Hitler rose to power without the use of any other arms than truncheons and revolvers. His propaganda was conducted mainly by addressing mass meetings in person. He was never allowed to use the wireless; while the Government which he overthrew had both this and modern weapons at its command.

I shall not follow Professor Oliver in his enquiry whether there can or cannot be morality without religious sanction; but I wish to express my agreement with most of what he says on this subject. I agree with him particularly in his approval of Miss Emmet's thesis—that truth is worth pursuing, the importance of justice and fairmindedness, respect for freedom of spirit, the conviction that we can to some extent recognise nonsense when we see it, and the recognition that man can

interpret experience in more than one way. The purpose of my paper was to point out that these presuppositions which represent in fact the minimum requirements of liberalism are not accepted any more by a very large part of European opinion. That on the contrary these assumptions are held in contempt, as vague and deceptive and looked upon as mere cant, intended (consciously or unconsciously) to rationalise or conceal the real motive forces. That human affairs are thought to be governed in reality by economic interests and the will to power—while all the talk about justice, freedom, etc., is regarded as mere ideological chatter. That is the problem which my paper set out to discuss.

Let me turn next to another interesting point raised by Principal Holt (and also alluded to by Professor Oliver), about religious intolerance. I am glad to take this opportunity, denied within the space of my paper, to refer to this question. Religious intolerance was practised by both Catholics and Protestants until the middle of the 17th century, at which time Protestants began to give up the claim to impose their creed on others, whence sprang the doctrine of tolerance in Holland, England and America which has never been shaken since. At the same time there occurred a sharp recrudescence of Catholic intolerance in France under Louis XIV, and Catholicism still recognises to-day the theoretical justification at least of the doctrine of intolerance. The differences between religious and totalitarian intolerance however are profound. The imposition of religious dogmatism was in general not an act of the State but of a separate authority, the Church, which ruled human beliefs, while the State governed in all other matters. These two authorities never ceased to contest each other's domination over the fields in which they overlapped. Thus two distinct centres of power were established within society; a duality of a kind quite incompatible with totalitarian centralisation. Conditions were in many cases much nearer to the two party system of modern Britain than to the one party system to which Europe east of the Rhine is so prone to-day. Religious doctrine differs from Party Line not only by its more limited scope but also by its more permanent nature. Christian doctrine, even that of Rome, has been subject to evolution in the course of

centuries, but was never subject as is the Party Line to ideological somersaults recurring every few months or years. The Church itself therefore appears (even at its worst) far more closely tied down by its own doctrine, and far less inclined therefore to tyrannise and corrupt its followers by demanding their allegiance to sudden changes of orthodoxy than are totalitarian Leaders controlling their subjects through the Party Line. Finally, even where religious intolerance prevailed the State itself could be, and usually was, based on permanent legal principles. The King mounted the throne by right of succession, not by force; the conception that the law was a mere instrument of class coercion which in an enlightened community should be replaced by sheer violence aimed at expediency, had not yet been accepted by any ruler. Justice and respect for the law were still universally considered as the foundation of all government, and law and custom were in fact transmitted as a permanent framework of life through the centuries.

I hope nobody will read this as a praise of religious intolerance. I am not advocating a return to a Medieval system, nor do I agree with modern Catholic thinkers who regard Humanism and Science as a mistake. I have my own views, as have others, about the ways by which we may retrieve the situation into which a modern radical scepticism has landed us; but my task on this occasion was primarily to face the issue as fully as possible: trusting that in one way or another the spirit of man will rise to the challenge, once this is clearly placed in front of him, and will reassert successfully his never surrendered claims.

John Dalton and Manchester (1793–1844)

By H. McLachlan, M.A., D.D., Litt.D.

John Dalton was born at Eaglesfield, a village 2½ miles S.W. of Cockermouth, Cumberland, in 1766, and spent nearly two-thirds of his life in Manchester. One of a family of six, of whom three grew up, he was not born with the proverbial silver spoon in his mouth. He first saw the light of day on a chaff bed in the living and work room of a handloom weaver's thatched cottage; his ancestors on one side being husbandmen or artisans, and on the other, respectable yeomen. His homeland, parentage, and the Society of Friends into which he was born contributed much to the making of the man, especially, though not exclusively, in those characteristics marking him off from the so-called perfect gentleman. Endowed with a speculative mind, a soaring spirit, and an indomitable perseverance which never failed him, he had learnt and taught much, written a little, and lectured often, before, at the age of twenty-seven, coming to Manchester in 1793, the year of his first publication, a volume on Meteorology.

Seen in retrospect, it appears to have been the turning point of his life. The town, with a population of possibly 60,000, was still administered on what resembled feudal government, and not incorporated as a borough until 1838, though between 1750 and 1820 its population had increased sevenfold. Dalton spoke of it in 1794 as "a large and flourishing place", a description not inappropriate on the lips of a countryman at that date.

It is not easy to determine whether Dalton owed more to Manchester than Manchester did to him.

In the first decade of this century certain continental scholars, we are told, knew Manchester chiefly as a dismal city in Lancashire, where, for some reason, Samuel Alexander thought fit to teach philosophy to a handful of pupils in an atmosphere of sordid commercialism. A hundred years earlier, the town became famous far and wide as the place where the Literary and Philosophical Society had recognised the genius of John Dalton, a member of it for half a century, in office continuously for forty-four years, and its president for twenty-eight.

No Mancunian would claim that his native city has ever been a health resort. That was not the worst said of it in Dalton's day. Molesworth, the historian, described the district of which it was the centre as " one, the inhabitants of which still used an uncouth dialect, chiefly known by its smoking chimneys, perpetual rains " and " a lawless turbulence which embarrassed the Government, perplexed the legislature, and dismayed the inhabitants of the more favoured parts of the kingdom ". It was to the last count in this severe indictment that King William IV must have referred when he asked Dalton, on his presentation at court, " How are you getting on at Manchester; all quiet I suppose ", to which the Quaker replied: " Well, I don't know, just middlin', I think ". From all we know of Dalton it may be surmised that he could give His Majesty no precise information about radicalism in the town of his adoption. He lived through stirring times with no apparent interest in the causes or results of riots and political agitation—yet the Meeting-house he attended sheltered those who fled from the " Peterloo Massacre " of August 16th, 1819, and for months afterwards " its floor was stained with the marks of human blood ", with all of which Dalton must have been acquainted. Unlike Joseph Priestley, another distinguished chemist and quondam nonconformist tutor, Dalton was a Moses, a meek man truly, but a lawgiver in science, not a David, fighting to build a kingdom of men's dreams. For Priestley, science was at most a secondary pursuit; Dalton knew no other. Incidentally, be it said, he solved the difficulty, for a Quaker, of court dress in the royal presence, by wearing the scarlet gown of an Oxford D.C.L., an honorary degree recently conferred upon him, though, from his peculiar vision, colour was not to him as to other men.

Dalton came to Manchester alone, and remained single. That proved important in respect of friendships in the town and his constant devotion to scientific research. The joys of family life are only to be purchased at a price. No Quaker head of a humble household could have left home for work after each meal till nine at night, as Dalton did his lodgings, with a punctuality rivalling that of Kant, the famous bachelor

philosopher of Königsberg, by whose movements people set their clocks. Even Dalton's Thursday half-day at bowls and his pipes and porter at the Inn with his playfellows might have been threatened by clamant calls upon an impoverished benedick. Moreover, this weekly visit to the country, the Dog and Partridge at Old Trafford, formerly an old farmhouse, was not without its scientific interest. He brought bottles in his pockets and filled them with water for later analysis. So, too, on annual holidays in the Lake District, he regularly climbed mountains, measured their heights, collected air, ascertained dew-points, and returned to Manchester with fresh material for investigation. It is actually said that "for 42 years on the same day of the same month he ascended Helvelyn". Habits of punctuality and regularity must occasionally be relaxed by a man with dependents having claims upon his time and attention. Like his contemporary, Charles Lamb, Dalton was really a "born bachelor", with all the virtues, but unlike the essayist, with none of the vices of that class of freemen. Like Lamb, too, he was no misogynist. When asked why he did not marry, he pleaded lack of time. "Means" might have been a better word, and "opportunity" the best, for he would but she wouldn't. The fair widowed Quakeress was not to be won by ardent suit. Dalton always enjoyed the society of talented women, and belonged to a sect which recognised women as equals of men. However boorish in appearance, he could not have been without attractions for a Quakeress seeing below the surface. He was fond of music, and, unlike Quakers in general, did not regard it as unseemly at Meetings for Worship. He was a good penman, an excellent correspondent, and, upon occasion, under the inspiration of Cupid, could even write verse. Simple in his tastes, he enjoyed the pleasures of the table, and was not one who, in Johnson's words, "have a foolish way of pretending not to mind what they eat". On excursions into the country or visits to Town, he made careful note of what his meals consisted, and, being accustomed to practise strict economy, of what they cost.

What did this man bring to Manchester and Manchester give to him?

Answers related only to what is material cannot explain the character or even the activities of Dalton. Neither his rustic forbears nor the environment of his outer life, separately or together, can account for the most formative element in his being. That was religion. True, one's religion may be but a formal acceptance of traditional rites and dogmas expressed in conventional worship, but never for a man of deep conviction, least of all for a Quaker. In Quaker speech, a traditionalist in religion was a "professor", amongst early Dissenters an honourable term for a Christian within the covenant of a Church but with Quakers a scurrilous term, like "steeple-house", or "priest", conceived as the would-be mediator in the relation of man and God. Early Quaker preachers were "Publishers of Truth", and Truth, spiritual and factual—the line between the two being indistinct—was realised by the Light Within, and governed Friends in matters great and small. A meticulous respect for Truth dictated the singular repudiation of the ordinary nomenclature of days and months, of current grammatical usage, and of common courtesy in word and deed, all of which seemed to imply some measure of disloyalty to the God of Truth. Science itself might have been defined by Dalton as the by-product of a disinterested love of truth. It is probably not without significance that nearly seventy Friends have been Fellows of the Royal Society (including one of the first two women elected in 1945), relatively a large number for so small a religious community.

Dalton, though more fluent as scientist than Quaker, was a seeker after Truth, human and divine. Speech may be silvern: for a Quaker silence is golden. It is the appointed way leading through apprehension of Truth to the divine presence. Quietism had now fallen upon the Quaker Meeting, and on "first-day" I suspect Dalton seldom raised his voice. On the rest of the seven he was a man of few words, not always choice, nor invariably governed by consideration for others, but, when Truth was involved, dictated by reverence.

As a courtier, diplomatist, or lawyer, Dalton must have miserably failed. With none of the three had he anything in common. As a teacher, despite natural disabilities and errors

of method and manner, he succeeded, and, amidst all his scientific research a teacher he remained almost to the end of his days.

By their very doctrine of man Quakers had what they call a "concern" for education, bringing out what might be dormant, but never dead, in any son of Adam, though for long their teachers were untrained save in the school of experience. Dalton's first school was in the Meeting-House of his native village. He began teaching in his father's barn whilst himself a child of eleven or twelve, and in 1781, at fifteen, after working in the fields, he returned to it (continuing his own studies under direction) when he and his brother Jonathan joined their cousin George Bewley in his school at Kendal. Four years later the brothers took over the school. Jonathan might have sat for Hood's portrait of "The Irish Schoolmaster":

> He never spared the rod and spoiled the child,
> But spoiled the rod and never spared the child.

John was more merciful. He only held the culprits whilst his elder brother did the flogging. The two offered to teach Latin, Greek, and French, with which they had a nodding acquaintance, and scientific subjects of which they could boast a much more extensive knowledge.

During his dozen years in Kendal Dalton, driven by necessity, read freely what other men wrote. In Manchester he did not. It was said of Priestley's friend Kippis that he had crammed so many books into his head that his brains refused to move. That could never be said of Dalton. He used to say: "I could carry all the books I have ever read on my back." One reason was that he now confined himself in the main to studies in which he was more or less a master. His was a single-track mind, moving independently on its own lines, but not without running at times less profitably than it might, if he had seen the lights on the way, or occasionally diverged from his own appointed path. What he had not discovered could hardly be said to exist for him. Ultimately, his self-reliance and independence of other minds derived from the Quaker habit of submission only to an authority within. Certainly Dalton never fled the printed word as a plague, for he regularly spent

part of his midday respite from labour at the Portico Subscription Library in Mosley Street after it was opened in 1805.

In 1793 he was recommended by his old teacher John Gough, of Kendal, to Dr. Thomas Barnes, principal of Manchester College, then in need of a teacher in science. Gough, blind from the age of three, was a mathematician of repute, and, more surprisingly, had trained himself to be a competent botanist. Wordsworth alludes to him in the seventh book of the "Excursion". Quaker by birth and liberal in theology, Gough turned Unitarian, worshipping in the Kendal chapel, of which from 1812 he was a trustee. A recommendation from such a man would go far with Barnes, and Dalton was the only Quaker who ever taught in a nonconformist academy.

Science was given an honoured place in Manchester College, as earlier in Warrington and other academies. In his sermon at the opening of the College in 1786, Dr. Barnes said:

> "Of all subjects divinity seems to demand the aid of kindred, and even of apparently remote sciences", and proceeded to name "natural philosophy" as relating to "the history or properties of the works of nature", "anatomy and physiology" as relating "to the body", and "metaphysics, moral philosophy and history" as relating to "the mind of man".

Dalton's subjects in the prospectus of the College, 1798, are "Mathematics and Geography, Natural Philosophy, and Chemistry, theoretical and experimental". Sir Henry Roscoe says there is no evidence that before 1796 Dalton "had taken any special interest in *chemical research*, or even had carried on practical laboratory work. His first introduction to the science seems to have been a course of lectures on chemistry which he attended, given by Dr. Garnet in Manchester". That may be true of "research" and "laboratory work", but Chemistry was taught by him in the College from his appointment in 1793.

The College, situated in Mosley Street, was described by its promoters as "an elegant pile of buildings in an airy and pleasant part of Manchester", or, as Dalton said, "in the most elegant and retired street in the place". The immediate

vicinity was still residential, and not until 1832 was there a warehouse in Mosley Street. During its seventeen years in Manchester (1786—1803) the College educated 135 men, of whom only twenty were divinity students, including four episcopalians. The library, some 3,000 volumes, had been largely inherited from Warrington Academy, and, in addition, tutors and students had the use of Chetham's Library, the first free library in England, described by Dalton as "large, furnished with the best books in every art, science, and language", an unconscious exaggeration betraying his ignorance of books and libraries. In 1791 the Library, according to the catalogue, contained only 6,723 works. If Dalton made little use of Manchester's books, this cannot be said of its apparatus used in his teaching at the College, and, during his early years in the town, in his experiments. The College also provided Dalton with an opportunity for more congenial and advanced teaching than was open to him at the school in Kendal. It secured for him a stable, if relatively meagre income (£80 minimum for session of ten months, with room and commons provided for £27. 10s.), and left him leisure for private tuition and research. In the College Report of 1797 it is said (quaintly as it now appears) that he "had uniformly acquitted himself to the entire satisfaction of the Trustees", and was "happy in possessing the respect and attachment of his pupils". It was "hoped that with the growing prosperity of the College he will enlarge his sphere of reputation and usefulness". Happily Dalton's reputation was not destined to depend upon the prosperity of the College in Manchester, for that was never anything to boast of. An old pupil recalled that "he was a very quiet teacher". Another, who had missed one lecture, applied to him for a certificate of full attendance. Dalton at first declined to give it; but after thinking a little, replied: "If thou wilt come to-morrow I will go over the lecture thou hast missed". In 1794 he had twenty-four pupils and wrote:

> "My official department of tutor only requires my attendance upon the students 21 hours in the week, but I find it often expedient to prepare the lectures previously."

Twenty-one hours attendance did not mean as many given to lecturing. Dalton did not believe in "spoon-feeding", and left his pupils to learn for themselves what he thought they ought, whilst he went on with other work. His labours did not end in the classroom, for he told his friend: "The watchword for my retiring to rest is 'Past twelve o'clock, cloudy morning'"; in other words, he ceased work at the cry of the night-watchman on his round. Some of his pupils made their mark in the world, amongst them, John Ashton Yates, M.P., Samuel Hibbert-Ware, M.D., Benjamin Gaskell, M.P., and John Thomson, M.D., president of the Royal Medical Society, Edinburgh.

Dalton's colleagues on the staff were notable men, and their daily contact with a young man largely dependent upon oral communication for news of the world outside the College cannot have failed to influence his intellectual development. Naturally as a Quaker he was at home amongst non-subscribers to creeds and lovers of religious liberty. On doctrine he was reticent, but attended Meeting twice on "first-day" and to the last wore the quaint Quaker dress. Thomas Barnes was the only minister of religion who was an original member of the Literary and Philosophical Society, of which he was joint secretary five years from its foundation, and remained a member until his death. The classical tutor was William Stevenson, minister of Dob Lane Chapel, Failsworth. His resignation in 1796 of both offices followed a violent change of opinion. He gave up the pulpit owing to scruples in regard to a paid ministry, though Dob Lane (paying £40 a year) did not offend greatly in this respect.[1] He may have accepted from Dalton one of his Quaker principles. His altered view of classics is seen in the Tract published on resigning his tutorship, "Remarks on the very inferior utility of Classical Learning". He afterwards edited the *Scots Magazine*, and in 1808 became Keeper of the Records for the Treasury. His daughter was Mrs. Gaskell the novelist. George Walker, F.R.S., principal 1798—1803, a former mathematical tutor at Warrington, was a scientist who suffered ostracism for radical political opinions, and, in 1804 succeeded Thomas Percival as president of the Literary and Philosophical Society. Another remarkable man who became an intimate

friend of Dalton was William Johns, son of a poor Pembroke farmer, who at sixteen knew no English, became a classical scholar, was tutor at the College for a year and was then compelled to retire from ill-health and straightened circumstances. Subsequently, for twenty-seven years (1805-32) he conducted a successful school in Manchester and had charge of a Unitarian chapel. Dalton resigned his tutorship in June, 1800, when the College was in deep waters, and was living in lodgings. Johns settled in Faulkner Street near the George Street home of the Literary and Philosophical Society (erected 1799), where, in one of the lower rooms, Dalton had been provided with a study and a laboratory. He is not credited with having been a great experimentalist. It is not surprising. He now made his own apparatus, always inexpensive, often rude, with which, however he sometimes worked wonders. Sir Henry Roscoe described one specimen of it as "a penny ink-bottle with a tube fixed in the cork", and Sir Henry Holland, who often visited Dalton, spoke in his *Recollections* of "his rude laboratory of broken bottles and other uncouth apparatus". Johns joined the Society in 1805, was joint-secretary with Dalton for three years and a vice-president for six. W. C. Henry, Dalton's first biographer, tells in the words of Miss Johns how Dalton came to reside with her father :—

> "As my mother was standing at her parlour window one evening towards dusk, she saw Mr. Dalton passing on the other side of the street, and on opening the window, he crossed over and greeted her. 'Mr. Dalton', said she, 'how is it that you seldom come to see us?' 'Why, I don't know,' he replied; 'but I have a mind to come and live with you'. My mother thought at first that he was in jest, but finding that he really meant what he said, she asked him to call again the next day, after she should have consulted my father. Accordingly, he came and took possession of the only bedroom at liberty, which he continued to occupy for nearly thirty years . . ."

As those years passed, there came to the Faulkner Street dwelling of William Johns many eminent scientists to pay their respects to John Dalton. Probably no Manchester home attracted

such distinguished visitors before, and none since, save that of Mrs. Gaskell in Plymouth Grove. In the year 1826, when Dalton had achieved a European renown, M. Pelletier, a well-known Parisian *savant*, came to Manchester with the express purpose of visiting the illustrious author of the Atomic Theory . . . What was the surprise of the Frenchman to find, on his arrival, that the whereabouts of Dalton could only be found after diligent search; and that, when at last he discovered the Manchester philosopher, he found him in a small room of a house in a back street, engaged in looking over the shoulders of a small boy who was working his "cyphering" on a slate. "Est-ce que j'ai l'honneur de m'addresser à Monsieur Dalton?", for he could hardly believe his eyes that this was the chemist of European fame, teaching a boy his first four rules. "Yes," said the matter-of-fact Quaker, "Wilt thou sit down while I put this lad right about his arithmetic".

Among Dalton's friends was Robert Owen, of New Lanark fame, and in his room at the College, Owen and a few others used to meet regularly for discussion. According to Mr. Cole, Owen's biographer, "They discussed moral and religious questions and the recent discoveries in chemistry and other sciences, and at one of these meetings, Owen tells us, Dalton first broached his atomic theory.

On several occasions, Samuel Taylor Coleridge, then under the spell of the French Revolution, visited the group. Owen gave full vent to his anti-religious opinions. By-and-by the College authorities became nervous, and Dr. Barnes asked that these meetings should be held less often on College premises. The group then moved elsewhere". We may be sure that Owen and Coleridge talked and Dalton listened, except when science was under discussion. We know that when Dalton lived with Johns, and friends dropped in, "he took little part in the conversation, in politics none whatever, nor for years had we any idea what his views on the subject were".

When Johns gave up his school Dalton found fresh lodgings. He still taught privately boys and girls at trifling fees, and gave numerous lectures on Natural and Experimental Philosophy, attended for a time by students of Blackburn Academy (est.

1816), now Lancashire Independent College. His most famous pupil was James Prescott Joule, the eminent physicist, who was born in Salford, lived in the Manchester district all his life, and was for forty-seven years a prominent member and officer of the Literary and Philosophical Society. Another pupil at Faulkner Street was John Edward Taylor, then a lad of fifteen, who at thirty founded the *Manchester Guardian*. Johns migrated to Great Cheetham Street, where his daughters opened a school, soon removed to a large house in Great Clowes Street, called "Eaglesfield" after the birthplace of Dalton. To a pupil of this school, daughter of Dr. John Relly Beard, the Literary and Philosophical Society was indebted for its last contact (March 4th, 1902) with one who had known Dalton in the flesh. As a girl of nine she had gone with Miss Johns to take tea with Dalton, and more than sixty years later went to hear her brother, Professor Arthur Dendy, lecture to the Society, when she related to the secretary her experience of the great man. Catharine Johns married Professor Eaton Hodgkinson, a friend of Dalton, who from 1848—1850 was president of the Society. In a codicil to his will, Dalton cancelled a bequest of £2,000 to promote the teaching of chemistry at Oxford "in order to provide more largely for the family of his friend the Rev. William Johns, who had sustained in his old age a heavy pecuniary loss".

Dalton's first visit to London, May, 1792, was to attend the yearly meeting of the Friends; his second, eleven years later, to deliver a series of lectures on science at the invitation of the Royal Institution of Great Britain.

He was never at home in the metropolis, and described it as "a surprising place, well worth one's while to see once, but the most disagreeable place on earth for one of a contemplative turn to reside in continually." Dalton was an impenitent provincial, rather proud of his command of the Cumbrian dialect, and neither his speech nor his manners favourably impressed Londoners. In 1822 he visited Paris, where he was made a lion of by distinguished French scientists, whose respect for his discoveries was probably greater than their acquaintance with the niceties of English polite society. With little conscious

effort, Dalton steadily climbed the ladder of fame, and made many new friends without dropping any of the old, a difficult feat, seldom performed by men who start at the foot of the ladder.

What the College did for Dalton in various ways during his early residence in Manchester was continued and extended throughout the rest of his life by the Literary and Philosophical Society, which published his researches. On the other side, it must be frankly confessed that his contributions to the Society's *Memoirs* raised it in the esteem of scientists at home and abroad from a provincial meeting of more or less reputable scholars interested in a curious variety of subjects to one from whose proceedings they had much to learn. Dalton read 116 papers before the Society, the first of which, in 1794, was on his péculiar vision, which we call "colourblindness", but which for some time was called after him, "Daltonism".

John James Taylor, a scholarly young contemporary of Dalton and later principal of Manchester College, writing (September 12th, 1822) to his old tutor at York, John Kenrick, M.A., observed: "Mechanics and chemistry are all the vogue in this district . . . Literature is quite beat off the field by science—even though we have a *Literary* and Philosophical Society". So far as the Society was concerned, this was the work, not of its founders, but of Dalton, and the tradition thus established was maintained, leading Dr. F. A. Bruton to observe in his *Short History of Manchester and Salford* published in 1924: "The Literary and Philosophical Society has been so much more scientific than literary that its title is almost a misnomer". Dalton was not the only member of the Society who had something to teach the world of science outside Manchester, but his dominant personality shaped its policy, for better, for worse, whilst his genius and long tenure of office so closely identified it with himself that during his lifetime it was almost impossible for scholars outside the County Palatine to think of Manchester without thinking of Dalton and the Society over which he presided.

Honours were freely bestowed upon him, from two universities and many learned societies in England, France, Germany, and Russia, Edinburgh gave him the freedom of the city, offers of honourable and lucrative employment outside Manchester were declined, and he became a recipient of the Royal Bounty He remained a simple-minded Quaker, generous in modest affluence as once prudent in poverty In 1795, when Manchester Friends built their present Meeting-house (the Society's third), Dalton, at a time when he could ill afford it, gave £50 towards its cost In his last illness he was carefully tended by his most intimate friend, Peter Clare, a clockmaker by trade, one of the secretaries of the Society, and an executor under his will He died July 27th, 1844 and was given a public funeral by Manchester, whose memorials honour the city no less than its most celebrated citizen These memorials, including statues, busts portraits, a lecture, university scholarships and prizes, a university hall of residence and a street in the city are more numerous than those of any other man

In the Unitarian College, Manchester is a pen-and-ink sketch of Dalton, signed by him, dated 1840 Beneath the sketch are the following manuscript lines

" Not mid the warring world's unhallowed strife
Was twined the laurel wreath that binds thy brows,
But with the true devotion of a life
To the pursuit of glorious Truth resigned, didst thou
With her true worshippers thy forehead bow
Pure and unspotted is thy well-worn face,
Which future times will own, as we do now,
Writing while human records shall remain,
With Kepler—Newton—Dalton's honoured name "

The Atomic Theory.*

By A. D. Ritchie.

My purpose is to try to show the part that Dalton played in converting an ancient theory, originally purely metaphysical, to scientific use and so making it the basis of the whole of chemistry. The essentials of what he said can be put very simply: it was its simplicity that made it important. Dalton argued that if we visualise the structure of a gas, the character of the minute parts in virtue of which it is elastic and compressible, we see they must be separate, distinct units If the gas is elementary, like Hydrogen or Oxygen, all the units must be alike in all respects, including weight. The weights of the units of different elementary gases must be supposed to be different. If two elementary gases combine to form a compound, they must do so in pairs, one of each, or in threes, one of one, two of the other, or in fours, and so on. Hence the relative weights of elements which enter in combination must be always the same or, if they differ, be simple multiples of the least weight. These combining or equivalent weights can be ascertained by chemical analysis. What can be seen to be true of gases may be supposed to be true of other substances.

Thus the analytical chemist was provided with a standard of accuracy; with a motive to pursue his task and improve his methods; with a notation in which to express his results, and chemical theory and chemical practice indissolubly wedded together. After Boyle's initial distinction between elements, compounds and mixtures, and Lavoisier's realisation of the significance of quantitative methods, Dalton's was the next and, in a sense, the final step in establishing chemistry. Nevertheless Dalton's work has been a centre of controversy—but that was really settled in 1896 by Roscoe and Harden in their *New View of the Origin of Dalton's Theory*. There was also, what is far more interesting, a curious fog of confusion in the thought of Dalton and his contemporaries. Whereas Physics has been relatively free of confusion of thought and progress has consisted mainly of extending and widening ideas initially

* Portions of this discussion have appeared in the proceedings of the Aristotelian Society, 1944-45, under the title, "The Atomic Theory as Metaphysics and as Science".

valid, chemistry from early times was nurtured in confusion; confusion that was not finally cleared up till about the middle of the 19th century, forty years after Dalton did his work. If you are in the very thickest fog you are not confused because you see nothing to confuse you. But as the fog gradually disperses you catch sight indistinctly of a bit of something here and another bit of something there; you are not quite sure what each is or how it fits in with the rest. Then you are confused, until it is clear enough to see everything.

I have used the analogy of a fog for mental confusion, but it fails in one respect, for fog is visible and is seen to be the cause of the confusion. But Dalton and his contemporaries did not think they were confused in their ideas, any more than we do. The honest ones thought that things were very complicated and reliable observation very difficult, the less honest ones thought that other people were very stupid or fussy to raise quibbling objections to nice simple theories. Of course things are complicated and observation is difficult, but confused thinking makes them more so.

Like many highly respectable scientific theories, the atomic theory began its career as metaphysics. I am not using "metaphysical" as a term of abuse or "scientific" as a term of praise, but using them significantly to mark a technical distinction, which should become clear by considering the arguments used for and against the atomic theory in ancient times. Perhaps I should add that the metaphysical part of what I have to say is easy because it is the metaphysics everyone uses. The scientific part involves some technicalities and is not quite so easy.

It must be emphasised at the outset that before the complications introduced by 19th and 20th century theoretical physics, matter or body or corporeal substance meant very much the same thing to everyone, whether philosopher, scientist or plain man. It meant that which is apparent to sight and touch, which occupies space and moves about in space. People's views about matter were metaphysical from the time when they began to make the distinction between appearance and reality; to argue that some appearances are more real or genuine than others and that there may be things which are real yet not

apparent. The arguments take the form : in spite of appearance to the contrary something must be so and so because any alternative is self-contradictory or inconsistent with an accepted truth. The argument is based on the assumption that logic can correct experience. Thus it has been argued that, although it is a familiar fact of experience that things come and go, appear and disappear, change, grow and decay, yet this is all appearance only and that what really and genuinely exists is unchanging and constant. The majority of men of science have accepted this metaphysical doctrine and indeed it is the starting point of the atomic theory.

The next step is to point out that if matter is neither destroyed nor created there must be material things which are real but too small to be visible or tangible. Thus we say that evaporation or condensation of moisture has taken place when things go dry or damp, though nothing visible passes out or in. We argue that invisible moisture must have passed out or in. We notice considerable changes produced by the cumulative effect of insensible processes. One drop of water falling on a stone makes no difference we can discern but the dripping of years wears it away, therefore we argue that each drop must actually wash away something. Granted that there are permanent real things too small to be sensible, it is then argued that there must be empty space between them. This explains how large visible things can be changed or destroyed although nothing is really changed or destroyed ; they are pulled apart and disintegrated as they could hardly be if they were as homogeneous and compact as they seem. Again, unless there is empty space between the things which really fill space it is hard to understand how movement can occur. The last and most telling argument of all is the compressibility of gases. But the force of this argument could not be seen till the 17th century when the study of gases began. The other arguments are to be found in Lucretius and were not new in his day.

The attraction of the atomic theory and the basis of the traditional arguments for it rest upon the process of visualising the minute structure of things, making the natural assumption that all physical operations are like our own operations on material things, namely by pushing them about. Pushing

requires, first, contiguity in space between pusher and pushed and, second, free space in which movement can occur. If the visualising process be carried through systematically and the analysis taken down to what can be supposed genuinely contiguous, then the classical atomic theory can hardly be avoided; we must end up with separate, distinct, indivisible units and empty space between.

The atomists, however, did not have it all their own way. Though in the 17th century Boyle, Newton and other leading English thinkers were atomists, many of the Continental ones were not, notably Descartes and Leibniz. At that time the position of the anti-atomist was unshakeable as long as he refused to visualise the minute structure of things and dealt only in terms of visible processes. What is more, he could point to certain incoherences in the atomic theory. The opposed theory assumes that matter is infinitely divisible; that there is no empty space anywhere but only greater or less density of matter, and that action is not by impact but by attraction or repulsion without contact. I shall call this the *plenum theory* because the denial of empty space is its most important difference from the atomic theory. It should be mentioned that some thinkers combine the two theories.

Supporters of the plenum theory have pointed out serious difficulties in the atomic theory. (1) The notion of things being separated and yet separated by nothing seems absurd, and yet that is what empty space means. (2) If the atoms are supposed to have a finite volume then they possess, at least, spatial parts, are therefore potentially divisible and not strictly atomic. While if they are supposed to have no volume but to be of the nature of massive points they must all equally have infinite density. Not only does infinite density seem absurd but it makes it harder for the atomic theory to account for different properties of things in terms of different kinds of atoms. Massive points can differ only in mass, whereas atoms of finite volume can differ also in density and be allowed to have spatial form and structure. But if this view be accepted awkward consequences follow. (3) In the classical form of the theory atoms are supposed to act on each other by impact. If two bodies approach, touch and then separate, at the moment

of contact they must be deformed or there is no real contact. Deformation on impact is conceivable in a composite body like a billiard ball by means of change of relative position of its component parts and in virtue of its containing some empty space. Deformation of a really simple body is inconceivable, so therefore is contact between two simple bodies. Hence atoms must operate by means of attractive and repulsive forces acting at a distance. On the alternative that atoms are massive points contact is equally inconceivable and action at a distance must even more obviously be admitted. But action at a distance, such as electric and magnetic attraction and repulsion, implies that space is not really empty but is a medium in which things are happening and may be only a very sparse kind of matter. The supporter of the atomic theory must either ignore these difficulties (as he usually does) or else make such concessions to the plenum theory that his own seems superfluous or at least very foggy.

But the upholder of the plenum theory has his own troubles for the effort to refuse to visualise the minute structure of things is not always so easy. An ancient controversy brings this point out clearly. The Greek atomists argued that to account for the way a fish swims through water you must assume that the water contains some empty space and, although apparently incompressible, is not entirely so. Otherwise how can you visualise the way in which the water is pushed away in front of his nose, flows backwards and in behind his tail so as to let him move ahead. Against this the Stoics argued that all these suppositions are entirely unnecessary. All that is required is to attend to observable facts. The fish produces a region of high pressure in front of his nose and of low pressure behind his tail. A fluid is by definition that which flows from a region of high pressure to one of low therefore the water flows backwards and the fish moves forwards. The argument is very logical, of course, but it sounds like a verbal dodge. In fact we find it difficult not to visualise. If we do, then atoms and empty space provide the explanation.

Atomic theory has always emphasised sharp distinctions and definite boundaries. Real things occupy definite limited volumes and between them there is nothing. A thing acts where it is

and nowhere else. The plenum theory obliterates all sharp distinctions. In a sense it makes everything spread everywhere. What seems the spatial place of one thing is only a nuclear region of specially intense occupation. This kind of argument also obliterates the qualitative distinctions between things. A piece of iron displays iron-like qualities because and to the extent that iron-like material is predominant in that region of space where we say the iron is, but to some extent other properties of interpenetrating things are present there too if we take the trouble to find them. According to this argument it is very doubtful whether anything has quite definite specific properties. Atomic theory on the other hand has always emphasised specific properties. Atoms are of different and definite kinds with definite properties. If any piece of matter is an aggregate of one kind of atoms it will display these properties only and no others, and will be noticeably homogeneous. Therefore if the properties of anything are unspecific it is because it is impure or heterogeneous. This connection between atomic theory and specific properties was realised to some extent in ancient times but no use could be made of it till the technique for investigating specific properties had been developed. This marks the difference between a theory that is scientific and one that is not. If, given the theory, we can deduce that certain observable consequences follow and if we have the means of observing them, then it is a scientific theory. A theory from which nothing definite can be deduced or from which opposite consequences can be deduced never can be scientific. As long as possible deductions are beyond the range of observation because of deficiencies of technique, the theory is not yet scientific. That was the condition of the atomic theory in Newton's day, as he recognised; so far as the scientific problems of his time were concerned the theory made practically no difference. "Hypothesis" was the term he used to mark its non-scientific character and he called it the corpuscular hypothesis. Corpuscular is really a better term than atomic, but I have not used it as it is less familiar.

The physics of Newton's day was a physics of solids and liquids although the study of gases had begun, thanks to the joint efforts of his friend Boyle and his enemy Hooke. Newton

indeed went further and announced the basic principle of the kinetic theory of gases (Princ. II, Prop. 23), and Dalton quoted it as one of the starting points of his new theory.

The other starting point was the notion of specific properties. This notion was arrived at with difficulty. Alchemy with its belief in transmutation of metals implied a denial of specific properties. You start with lead which has a dull whitish colour and if you are clever enough you transform that into a bright yellow colour; and there you have gold. Why not? We see every day some properties of things being changed while others are not. What is more, the ancient and useful process of cupellation does successfully turn lead into silver. The alchemists with the help of reagents such as mercury and nitre did in fact produce startling though less economically profitable transformations. So why not lead into gold? Newton, quite late in life, in the long query he appended to the 2nd Edition of his *Opticks*, could still state, on Boyle's authority, that water several times distilled leaves a small earthy residue when evaporated. This was taken to mean that some water is transformed to earth. He also said that mercury at ordinary temperatures might be solid and not liquid. But fifty years earlier Boyle had stated contrary principles, which are now the basic principles of chemistry, though they were far from obvious and took a long time to establish. Boyle realised that traditional theory which made earth, water, air and fire elements, or later theory in terms of salt, sulphur and mercury, suffered the fatal defect that there was no relationship between theory and practice, what the chemist actually did in his laboratory Now what he does, or should do, is to separate mechanically the different kinds of things, so that they can be put into different bottles and labelled, and to ascertain their properties when separated. Nobody, as Boyle pointed out, ever extracted earth, water, air or fire out of gold; nor yet salt, sulphur or mercury unless he first put them in. On the other hand, gold can be alloyed with other metals or dissolved up in acids and then recovered again entirely unchanged. Therefore, if there are such things as chemical elements, gold is a much better candidate for the post than any of these fancied principles. Chemical theory should arise out of chemical practice and

chemical practice be directed by chemical theory; the two must form a compound not a mixture. Boyle's doctrine, fully developed, means that when things are found to be variable in their properties the chemist should try to separate out from them invariables—pure substances—whose properties are constant (apart from regular variation with temperature and pressure). If any one specific property of a substance is altered it can be done only by altering others, namely, by chemical combination or decomposition to form a new substance or substances. Clearly substances can be of two sorts; elements which cannot be broken down by chemical change into simpler substances, and those which can, compounds. Everything else is a mixture.

It might have proved too hard a task to separate things effectively. If it had been there would be no science of chemistry, and everything would remain inextricably mixed with everything else, as the plenum theory suggests. But the labours of the 18th century chemists who studied the metals and their compounds with oxygen, sulphur and acids showed that separation was possible. This was a nasty blow for the plenum theory and the death of alchemy. Then, as quantitative methods began to be developed, a new conception arose, that of definite combining weights. This new notion was not accepted without difficulty, as was seen in the long controversy in the opening years of the 19th century between Berthollet and Proust. Berthollet, applying dynamic analogies to chemistry, enunciated the law of mass action; a rule that is the basis of all modern theory of velocity of chemical reaction, but does not determine the composition of compounds formed in chemical reactions in the way Berthollet supposed. He claimed, for instance, that the quantity of oxygen or sulphur which combined with a metal varied according to conditions, so that combining weights were not definite or fixed. It is worth noting that Berthollet considered metallic alloys and solutions of salts in water to be chemical compounds and in the light of the knowledge of his day there was no very obvious objection. However, as regards oxides, sulphides and certain metallic salts, Proust was able to show that Berthollet was wrong. He showed that some metals form only one oxide or sulphide of

definite composition; others form two, but again each is of definite and distinct composition and properties. Proust discovered that metals form hydroxides as well as oxides and that ignorance of the distinction had led Berthollet astray. But Proust's victory over Berthollet was precariously based. Good luck or instinct led him to examine cases where only a few different compounds could be formed and where it was not very difficult to recognise a mixture as such. Had he tackled the naturally occurring fats or mineral oils the story would have been very different. Without the atomic theory to determine beforehand what are the criteria of a substance and how it differs from a mixture, separation in these difficult cases could not have been done.

It was during the controversy between Berthollet and Proust, namely, between 1802 and 1804, that Dalton made his discovery, but it is unlikely, in the midst of the Napoleonic Wars, that he knew much about the work of French chemists. In any case he approached the whole subject from a different aspect, the physical properties of gases. Dalton was primarily a physicist led in the direction of chemistry because his meteorological studies provoked the questions about the composition of atmospheric air and the absorption of gases by water. The properties of gases provide a natural approach to the classical atomic theory. In fact, the development of the kinetic theory of gases in the 19th century constituted, quite apart from any contribution from chemistry, the culminating triumph of classical atomic theory. Newton, though he made no further use of it, had stated the fundamentals of the kinetic theory (*Principia II*, Prop. 23). "If a fluid be composed of particles fleeing from each other and the density be as the compression [Boyle's Law], the centrifugal forces of the particles will be inversely proportional to the distances of their centres. Conversely, particles fleeing from each other with forces that are inversely proportional to the distances of their centres compose an elastic fluid whose density is as the compression." The statement is ambiguous. It applies to what may be called a pure kinetic system with no actual repulsion of particles, except elastic impact with each other and with the walls of the containing vessel. Or it might imply a field of repulsion between

particles. Unfortunately Dalton took it in the second sense. He also made the very natural error, based on the analogy of solids and liquids, of taking the density of a gas as a function of the volume of the particles, and not solely of their number and mass. In support of this he could quote the puzzling fact that steam is lighter than the oxygen it contains.

Dalton's view of the nature of gases, like that of most of his contemporaries, was far from clear. When Gay Lussac in 1808 suggested that the volume of gases that enter into chemical combination are as simple whole numbers, Dalton was not convinced, and had some reason for his doubts. His own analytical data, as well as published data of others, suggested that the rule was at best a very rough approximation. Apparently it could not account satisfactorily for the oxides of nitrogen, nor yet for steam if its formula was taken as HO, according to his rule of assuming the simplest formula. Of course, Avogadro's hypothesis of 1811 provided the solution, but a solution that was not obvious at the time and was not generally accepted till some thirty years later. Dalton seems to have thought of it or something like and then abandoned it. Avogadro had two points to make. First, the kinetic theory requires that at the same temperature and pressure the same volume of any gas should contain the same number of particles. Then, as a corollary, that the gas particle or molecule is not necessarily as simple as the atom or the unit entering into chemical combination. Nature played a cruel trick on the chemist in making the common elementary gases all diatomic. The difficulty was to realise that Dalton's new theory required not one but three notions: the molecular weight; the chemical combining weight or equivalent; and the atomic weight. The first two must be simple multiples of the third but need not be the same. In spite of the confusion of thought in his day, Dalton had grasped and his contemporaries quickly realised the one vital point for the science of his day; namely that every element in all chemical combinations has definite equivalent or combining weights and that this must be so if every atom of the same kind is of the same weight.

The immediate task was the accurate determination of equivalents. That could be done; it was only a matter of

improving existing analytical methods and of persistent hard work. The rest, the final touches of producing a consistent system of atomic and molecular weights could wait for the clearing up of the analytical data. This was the work of Berzelius, Gay Lussac, and the new generation of chemists. The necessity of improved analytical technique can be seen from the data that Dalton used. Errors exceeding ten per cent. were the rule rather than the exception. Why not? Set a class of elementary students to determine, say, the equivalent weight of zinc by dissolving it in acid and measuring the hydrogen evolved, and they will produce a wonderful variety of answers. Why not? If *A* differs from *B* why should *A*'s result be better or worse than *B*'s? The answer is given by the atomic theory. If that is accepted there is one correct result and any other is wrong. The experimenter who gets the wrong result must either be using impure materials, or bad methods, or be guilty of malobservation.

It was very fortunate that chemical methods had been standardised and a formidable body of analytical data collected and critically examined long before those meddling physicists began to talk about isotopes. When Lord Rayleigh discovered a small difference in density between nitrogen obtained from the the atmosphere and nitrogen from compounds he assumed, as Dalton did, that every atom of the same chemical element must be of the same weight. The assumption is not quite correct, but it led Rayleigh to the discovery of Argon and the opening of a new chapter in chemistry and physics. The notions of classical chemistry are approximations but approximations sufficiently exact to guide a hundred years of work. When finally it was discovered that two atoms might have the same chemical properties but different weights, or the same weight but different properties, an important clue to the new discovery came from the data that the chemists, using the older and opposite assumption had established; namely that the atomic weights of some elements refused to come out as whole numbers.

We now know that the atoms of the chemist, the Daltonian atoms, are not the supposed simple ultimate indestructible units of classical theory. They are highly complex and some are liable to explode with violence. But, given the chemists

task of separating single substances with specific properties within a limited range of temperature and pressures and using the classical methods, then they are the units that he finds indivisible and in terms of which he must report his results. More is not to be expected. It is not only in chemistry that one has to recognise entities which from one point of view are units and indivisible yet from another are complex and divisible. Biology has to deal with several. The living cell; the gene, the carrier of heredity, and the nervous impulse are all atomic and yet complex. The entities of physical theory, electrons, protons and the rest, appear to be the last and smallest units we can discover. In their case you will notice that traditional distinctions between atomic theory and plenum theory entirely break down; and new and very difficult problems arise.

Some Antibiotics with special reference to Penicillin.

By H. W. FLOREY, F.R.S.

It seems probable that moulds have been used in folk medicine by many different peoples, for example, in Central Europe, in the Ukraine, in Central America among the Mayans, and very probably in other places about which I have not yet heard. The first scientific observations, however, on what is known as "microbial antagonism" were made by Pasteur and Joubert in 1877. They noticed that if a culture of anthrax bacilli in urine was contaminated by organisms from the air the anthrax bacilli were destroyed after a shorter or longer time. They also found that by introducing the anthrax bacillus into the animal body in association with one of these common bacteria the death of the animal from the anthrax bacilli could sometimes be prevented. They remarked: "Tous ces faits autorisent peut-être les plus grandes espérances au point de vue thérapeutique". This work was not followed up by Pasteur himself, though in a letter to Dumas in 1880 he showed that fowls immunised against fowl cholera were refractory to anthrax. It is fairly clear that he had in mind the production by one organism of an immunity which would protect against another.

In 1885 another idea emerged, when Cantani proposed to replace the tubercle bacillus in the tissues of the lungs with an ill-defined organism called *Bacterium termo*. He did, in fact, treat a tuberculous patient by insufflating large amounts of cultures of this bacillus into the lungs, and claimed good results. This idea of the replacement of one pathogenic organism either by another less pathogenic or, if possible, by an innocuous organism occurs again from time to time in the literature; for example, Colebrook in 1915 proposed to treat carriers of meningococci by establishing pneumococci in the nose and throat. He hoped that the meningococci would then disappear especially as he had shown that they were antagonised by pneumococci in a broth culture. The observations, however, which gave the greatest impulse to the study of microbial antagonism came from Garré in 1887. Garré did experiments of the sort which are being done in many countries at the present time. He deliberately inoculated gelatine plates with different

kinds of bacteria in parallel streaks, in order to see whether anything produced by one bacterium would diffuse through the gelatine and stop the growth of others He noticed particularly that *Pseudomonas fluorescens* produced such an antibacterial substance

It was about this time that the word "antibiosis" appears to have been introduced into scientific literature by Vuillemin It was used to express the idea of the unfavourable action of one organism on the growth of another Relatively recently Waksman has proposed that naturally occurring antibacterial substances should be called "antibiotics", and the word is finding increasing use for this purpose

Several papers on the subject appeared soon after Garre's, but the most interesting from the historical point of view is the thesis by Doehle, presented at Kiel in 1889, for it contains the first illustration of bacterial antagonism I have been able to find It is of further interest that the photograph was actually taken by Hoppe-Seyler himself Thus, even by 1889 the phenomenon of microbial antagonism was well known and had been illustrated Not only Pasteur but nearly all the bacteriologists of that time had in mind the use of the phenomenon for therapeutic purposes in medicine, for instance, Emmerich showed that some effect could be obtained in protecting rabbits from anthrax by the simultaneous injection of a streptococcus from a case of erysipelas

But it was the observations of Bouchard in 1889 which started one of the most serious efforts which have been made to use a natural antibacterial substance in medicine Bouchard observed that a culture of *Bacillus pyocyaneus* could confer some degree of protection on animals injected at the same time with anthrax The next step was to use the metabolic products of the bacteria instead of whole cultures, and I think the first trials on man of such a product were made by Honl and Bukovsky in 1898 They described the treatment with *B. pyocyaneus* culture fluid of 100 patients with ulcer of the leg, some of them cases in which amputation had been considered. Their fluid, which they believed contained proteins from the cultures, was applied to the ulcers on wet bandages, with apparently good clinical results. At the same time, quite

independently, Emmerich and Löw were working with the same bacterium, and in 1899 prepared an extract which they called "procyanase". This, which was thought to be an enzyme produced by the *Bacillus pyocyaneus*, not only killed such organisms as *B. anthracis* and *B. diphtheriae* but also dissolved them. It was proposed at first to inject pyocyanase into the body in order to influence generalised infections. These attempts came to nothing and the subject became confused with untenable ideas on immunity, but as a local application pyocyanase came into considerable use in the clinics of Germany and Italy. At least 50 papers have been writeen on the clinical use of this material. It was particularly employed in the treatment of diphtheria, both in the acute stage and for carriers. It was also used for treating inflammatory conditions of the eye, for the treatment of meningitis and of carriers of the meningococcus, and it was even injected into the cerebrospinal fluid. It was also used for gonorrhœa. Nearly all the papers published at this time speak of good results from local application, but nevertheless from about 1908, which seems to have been the peak year, fewer and fewer publications about pyocyanase appeared and it eventually passed almost out of use, though it remained on sale as a commercial product in Germany at least until 1936. In 1929 Wagner and in 1932 Hettche tested the commercial pyocyanase of that day and found it to be quite inactive, but active pyocyanase can of course be made. Papers continued to appear right up to 1942 and indeed work on the products of *B. pyocyaneus* was done in the laboratory at Oxford during 1939 and 1940. Emmerich and Löw's idea that pyocyanase was an enzyme was soon attacked, and there were some very lively polemical articles in the German press at the beginning of this century. It was Raubitschek and Russ who pointed out that pyocyanase was of a lipoid nature. We know now that it consists of at least three substances which are all quite strongly bactericidal; two of them are dyes related to the flavines and compare favourably with flavine compounds used in medicine at the present time, and the third is lipoidal.

In 1903 an interesting paper by Lode appeared in which he described a coccus which dropped accidentally on to a plate

of *Micrococcus tetragenus* which he had prepared for a class Round the coccus there was a wide zone in which the *M tetragenus* had not grown Experiments showed that the coccus produced a diffusible substance which was heat-labile and that oxygen was needed for its elaboration, but he did not succeed in extracting it though he noted that it could be dried and was soluble in alcohol but not in ether He did some experiments to see if the metabolic product could be used for treating experimental disease in animals and though he considered his results disappointing he clearly had the right ideas

I can do no more than choose some examples from the very large number of papers in which bacterial antagonism of one sort or another has been recorded Many of the authors tried or suggested therapeutic applications

So far we have only considered examples of the products of bacteria, but fungi or moulds may also elaborate anti-bacterial substances, indeed one of the first of such substances to be crystallised came from a mould This was done by Gosio in 1898 from a *Penicillium* which is now known as *Penicillium brevi-compactum* The substance, mycophenolic acid was obtained only in very small quantities, and this he said, unfortunately prevented him from doing animal experiments, but he ascertained that it would stop the growth of the anthrax bacillus That I think, is the first example in history of the preparation of an antibiotic from a mould Again in 1913 Alsberg and Black during an investigation of the cause of pellagra, extracted from the mould *Penicillium puberulum* a crystalline antibiotic which they called penicillic acid This was found to stop the growth of *B coli* and to be toxic to animals They also did further work on mycophenolic acid and showed that it was remarkably non-toxic, a mouse tolerating as much as 10 mg injected subcutaneously

The first use in man of a mould as opposed to a bacterial product was apparently made by Vaudremer, reported in 1913 He stated that he had injected the culture liquid on which *Aspergillus fumigatus* had grown into 200 people suffering from tuberculosis *In vitro* he had found that *A fumigatus* was capable of destroying the tubercle bacillus although this apparently took some considerable time The observation is

of considerable interest because we now know that *A fumigatus* produces not one but four powerful antibacterial substances, all of which have been identified and crystallised They are gliotoxin, helvolic acid, spinulosin and fumigatin Vaudremer's experiments were unfortunately not backed up by any animal or pharmacological investigations, but I think this is the first instance that can be recorded of an attempt to use mould products in man

Some important work was done in the 1920's on the antagonistic effects of the actinomycetes These were first noticed by Lieske in 1921 But we owe most of the knowledge gained at this time to Gratia and Dath who deliberately set out to find antagonistic organisms by growing them from such sources as tap water pond water, etc on plates containing various pathogenic organisms They were particularly struck by the effects of a *Streptothrix* which caused the dissolution of the staphylococci with which a plate was heavily sown In the course of these investigations they also discovered a mould of the *Penicillium* family which did the same thing They developed a method of preparing vaccines in which the organism was dissolved by the *Streptothrix* instead of being destroyed by heat These special vaccines were called "mycolysates and production of very good immunity in animals and man was claimed for them They appear to have been extensively used in Belgium at least for the treatment of staphylococcal infections such as boils and furuncles In the same category is the work of Much who used a strain of *B mycoides B cytolyticus* Much— for the production of lytic substances His preparation was on sale for use in medicine under the name of 'Sentocym"

You will thus see that by the end of the 1920's there had been attempts to use in medicine the phenomenon of microbial antagonism in the following ways —

1 The replacement of a pathogenic organism by a less harmful one

2 Immunisation by one organism to protect against another

3 The use of soluble bacterial products to produce immunity to another organism and to treat established disease

4. The use of soluble bacterial products as a local application for the treatment of local infections.

5. The use of lytic substances from an organism for the preparation of vaccines of other species.

In addition we had already witnessed by this time the isolation of two crystalline antibiotics from moulds.

In 1928 Fleming made an observation on the inhibition of bacterial growth by a mould of the genus *Penicillium*. He was working on variation in colonies of staphylococci, work which entailed examining his plates at frequent intervals, which meant that the lids were lifted and that contamination in the course of several days became almost inevitable. On one of these plates, which had been left about a week at room temperature, a mould appeared which he noted to be remarkable in that it was dissolving the colonies of staphylococci in its neighbourhood. He subcultured this mould (which was subsequently identified as *Penicillium notatum*) in broth and found that it secreted something into the broth which had the power of stopping the growth and eventually of slowly killing many pathogenic organisms. Here then once more was an excellent example of microbial antagonism. He called the broth in which this antibacterial substance had been secreted " penicillin ". Later the antibacterial substance itself was given this name. Fleming observed that the broth acted on many important pathogenic organisms such as the streptococcus and staphylococcus, while others such as the influenza bacillus and the genus causing dysentery remained unaffected. It was thus clear at this early stage that penicillin had a selective action. The broth even when diluted as much as 800 times still exerted a bacteriostatic action—a potency at least 8 times greater than that of any antibiotic reported up to that time. He also found that he could inject 20 cubic cm. of the broth containing penicillin into rabbits with no more effect than that produced by plain broth, and the same applied to its effect on leucocytes. He also showed that the penicillin broth could be applied to the conjunctival sac without exciting inflammation. Some of his previous work had dealt with the estimation of the powers of antiseptics and he was struck by the fact that this was the first antiseptic he had encountered which appeared to be more destructive to bacteria

than to tissues and leucocytes. He observed that the material was soluble in alcohol and that it was destroyed by heating.

As a result of this work Fleming wrote in 1932—"In penicillin we have a perfectly innocuous fluid which is capable of inhibiting the growth of the pyogenic cocci in dilutions up to 1 in 800. It has been used on a number of indolent septic wounds and has certainly appeared to be superior to dressings containing potent chemicals. It is unlikely that it acts by killing the bacteria directly. . . . . The practical difficulty in the use of penicillin for dressings of septic wounds is the amount of trouble necessary for its preparation and the difficulty of maintaining its potency for more than a few weeks."

It is thus clear that Fleming's idea was to use penicillin broth in much the same way as pyocyanase had been used before, although there were good indications that penicillin would prove superior to pyocyanase. Fleming maintained his strain of mould and made use of the broth in differential culture media in the laboratory, but nothing more was done towards its introduction into medicine between the early 1930's and the beginning of the next decade. In articles written in 1940 and 1941 he explains in these words why he gave up:—"We have been using it in the laboratory for over 10 years as a method of differential culture. It was used in a few cases as a local antiseptic, but although it gave reasonably good results the trouble of making it seemed not worth while." And in 1941 he wrote: ". . . . a few tentative observations had been made on the effect of the local application of the unconcentrated culture to septic wounds (chiefly carbuncles and sinuses). Although the results were considered favourable there was no miraculous success" and ". . . . it was not considered that the production of penicillin for the treatment of these was practicable owing to the lability of the active principle in solution."

We now have to enquire why it became worth while 10 years later to make the great efforts necessary to produce it under the unfavourable conditions of war time—clearly some new and decisive factor had been brought into the picture. Briefly, this is that penicillin was discovered to belong to that rare class of drugs—the true chemotherapeutic agent, that is, a

drug harmless enough to be injected into the body or swallowed and yet able to kill bacteria causing disease, and thus to cure the disease. I shall proceed to explain to you the steps leading to this discovery.

In 1932 Clutterbuck, Lovell and Raistrick had published a paper in which they showed that penicillin could be produced by the mould on a synthetic medium. They also showed that the substance could be extracted from water into ether if the water was made acid, but that large losses occurred on the evaporation of the ether. They recognised that penicillin was most stable around neutrality but they stated that it was a very labile substance, and did not carry the work further.

My own interest in naturally occurring antibacterial substances dates back many years, and in 1929 I was working on another substance discovered by Fleming, lysozyme. In the succeeding years my biochemical colleagues isolated this enzyme and studied its substrate. In 1935 I was joined by Dr. Chain, a biochemist, and he, with Epstein, characterised the substrate. As this work proceeded Dr. Chain and I had many discussions on the possible interest of a systematic and thorough study of the known natural antibacterial substances, and it seemed to us that such a survey might prove well worth while from many academic, as well as practical points of view. Eventually three were chosen for the first investigation—the products of *B. subtilis* and *B. pyocyaneus*, and penicillin. Work was begun on the last two, and after some preliminary experiments it became clear that penicillin might be of outstanding interest and was worth intensive effort. This was in 1939, at the beginning of the present war, but I should like to emphasize that our investigation of penicillin had in the beginning no relation to the war but was undertaken as a purely academic study, part of a comprehensive research. It was soon clear that a team of workers with special knowledge in various branches of pathology, biochemistry and medicine would be needed for rapid progress, and finally at the Oxford School of Pathology were assembled for the work Dr. Chain, Professor Gardner, Dr. Abraham, Dr. Heatley, Dr. Jennings, Dr. Sanders, Dr. Fletcher, Dr. M. E. Florey and myself.

The first step was to grow the mould, and for this we had

the experience of Fleming and of Clutterbuck, Lovell and Raistrick to guide us The first cultures were made on the synthetic medium recommended by the latter workers, slightly modified One of the first essentials in undertaking the extraction and purification of a biologically active substance contained in a complex mixture such as culture fluid is to have a quick biological test which will enable one to follow the substance through the various chemical manipulations Dr Heatley provided this test The surface of an agar plate is first sown with a broth culture of *Staphylococcus aureus* or other suitable organism The excess broth is drained away and the plate dried in the incubator at 37° C Small cylinders of glass or porcelain are then placed on the surface and filled with the solutions under test Substances in solution in the cylinders diffuse out into the agar On incubation at 37° the staphylococci grow up into a confluent layer on the plate, but if penicillin is present in the fluid no growth occurs round the cylinders, where it has diffused out The diameter of the zones of inhibition bear a relationship to the amount of penicillin in the fluid This test is relatively easy to do and is quicker than serial dilution methods It has been of inestimable value for work not only on penicillin, but on other antibiotics also

At first culture was undertaken in Erlenmeyer flasks, but early in the work it became apparent that larger vessels would be required Each vessel, specially designed, holds 1 liter in a layer 2 cm deep, and this type was eventually employed for all our large scale laboratory work Clearly the first step in the work was to learn to extract the penicillin from the complex mixture of culture fluid and metabolites You will recollect that both Fleming and Raistrick had said that penicillin was a very labile substance The trick for its successful extraction was the knowledge that in the acid form it is more soluble in organic solvents than it is in water. It is true that in the acid form it is extremely unstable in water but this can be considerably diminished by cold It is thus possible to extract penicillin, as Raistrick had shown, in the cold from watery solution into an organic solvent such as ether by first acidifying the water. To get the penicillin out of the ether again it was

only necessary to shake the ether with about one-fifth of its volume of phosphate buffer at a pH of about 7, i.e. it would come back into a watery solution by the addition of a carefully calculated amount of alkali. Among other organic solvents which can be used, one of the best and most commonly used is amyl acetate.

Here briefly are some of penicillin's most important chemical properties. Salts such as the sodium and calcium salts are most stable between pH 5 and 7 (i.e. at neutrality). It is destroyed by the following : acids and alkalis, oxidising agents, heavy metal ions, e.g. Cu and Pb, primary alcohols and amines and by boiling and by enzymes produced by bacteria. I would particularly like to call your attention to the last factor, namely, the influence of a bacterial enzyme on penicillin. This enzyme, which was first studied by Chain and Abraham, is found in a large number of non-pathogenic and pathogenic bacteria, and is capable of destroying the antibacterial action of penicillin in an extremely short time. Unfortunately, many air organisms are of this type, so that the slightest contamination of the cultures of penicillin is likely to result in a completely inactive metabolism fluid. It is largely due to the existence of these enzymes that the large-scale manufacture of penicillin by commercial firms offers so many difficulties. You can imagine the really great skill required in handling large quantities of the culture fluid to ensure complete sterility. If it were not for this enzyme, penicillin would probably be as easy to make as beer. The extracted dry powder was an extremely active antibacterial agent against many pathogenic organisms and at first we thought we must be handling nearly pure penicillin, since it stopped the growth of such organisms as the staphylococcus at a dilution of at least 1 in 1 million. However, we know now that our early material contained not more than 1 or 2 per cent of penicillin, the rest being impurities. With this material the sensitivity of many pathogenic organisms was titrated by Gardner. The results were essentially the same as Fleming's with the addition of the gas gangrene organisms and the gonococcus to the sensitive bacteria and of the tubercle bacillus to the insensitive. The table shows the present state of our knowledge.

Sensitive	*Relatively or completely insensitive*
N gonorrhœæ	Salm typhi
N meningitidis	Salm enteritidis (Gaertner)
Staph aureus	H pertussis
Str pyogenes	H influenzæ
Str pneumoniæ	Myco tuberculosis
Str viridans	Listerella
Anærobic streptococcus	Past pestis
Act bovis	Bact coli
Cl tetani	Salm paratyphi B
Cl welchii	Bact shigæ
Cl septique	Proteus
Cl œdematiens	Ps pyocyanea
B anthracis	B friedlanderi
C diphtheriæ	V choleræ
Trep pallidum	Br abortus
Trep recurrentis	Br melitensis
H ducreyi	Lepto icterohæmorrhagiæ
Virus of psittacosis	Ent histolytica
	Viruses (majority)

All the above species are capable of causing severe infections in man

Penicillin shows some important properties in its antibacterial action, for example, it is little affected by the number of bacteria present, its efficiency is little impaired by pus, tissue autolysates, blood or serum and it kills dividing organisms and dissolves certain species, e g the staphylococcus One of the most important bacteriological observations was that penicillin retained its activity in the presence of blood, serum, and, most important of all, pus This activity in the presence of pus sharply differentiated penicillin from any of the sulphonamides known at that time and is naturally of the first importance in treating septic conditions

At the same time as the bacteriological investigations were in progress the pharmacological properties of the extract were being investigated Mice weighing 20 g were shown to tolerate doses of as much as 10 g intravenously, even of the first crude preparation This relative lack of toxicity we later found also

in rabbits and cats. As the work progressed it appeared that the purer the penicillin the less toxic it was, for example, Dr. Jennings and I found that material containing about ten times as much penicillin as our first extract was considerably less toxic, in that mice tolerated 20 mg. without any symptoms. This lack of toxicity of penicillin has now been fully confirmed, and it is clear that the pure material is almost non-toxic. We can count it as an extremely fortunate circumstance that the many impurities which pass through the extraction processes are themselves of low toxicity, so that relatively impure material can be used for clinical purposes. Not only was toxicity low after a single intravenous injection but repeated subcutaneous injections extending over several days were without significant effect on the animal—another point which has since been fully substantiated both in animals and man by other workers. It was shown also that quite strong solutions could be applied without damage to the brain and that white blood cells *in vitro* would tolerate a concentration of crude penicillin 2,000 times as great as that necessary to inhibit sensitive organisms, without impairment of their motility. Dr. Medawar and Dr. Jacoby showed the same wide ratio between the amount required to prevent bacterial growth and the dose which had toxic effects on body cells in tissue culture.

It was further shown in the experimental animal that after injection intravenously, intramuscularly or subcutaneously penicillin was rapidly excreted in the urine, thus making it clear from the outset that in order to maintain a concentration of penicillin in the body frequent or continuous injections were necessary. This fact of rapid excretion by the kidneys applies also to man.

From the fact that acid destroys penicillin fairly rapidly it was clear that attempts to give it into the stomach, which contains acid, were likely to be ineffective. This is the reason why, up to the present, if penicillin cannot be applied directly to the infected part, it has always been given by injection.

You will see then that we knew that we had an extract which was stable under certain well denfied conditions, was remarkably innocuous to animals, not only to the intact animal but to the various special tissues, and that the animal could

withstand a dose of the material thousands of times greater than that necessary to produce bacterial inhibition We had in the early stages of these co-ordinated investigations done a very small scale "protection" experiment in which mice artificially infected with streptococci were treated by injections of penicillin These tests had been quite promising so that we were not greatly surprised when we came to do a full scale set of mouse "protection" experiments, that almost complete protection could be given against fatal infections with the streptococcus and more important, the staphylococcus by injections at suitable intervals even of our crude preparations In addition it was shown that a fatal infection of mice with a gas gangrene organism could be controlled These were the crucial experiments from which we knew that penicillin belonged to that rare class of drug—a true chemotherapeutic substance You will now understand why what did not seem worth while in 1930 became so much worth while in 1940 that every effort was called for to produce the drug You can perhaps imagine our state of mind when we contemplated the enormous difficulties in producing this substance which were added to by the shortages of men and materials due to the war Here we had something which would almost certainly be of the greatest value not only for grave infections but also for the treatment of septic war wounds but the prospects of getting a substantial amount appeared very slight The first step was to make, by the methods we then had in use, sufficient penicillin to try its effect on human disease This was accomplished, and in the course of some ten months or so we produced enough in the laboratory to treat the first few cases and to show that our animal and other experiments had not misled us as to what might be expected in man It was the success of these trials which led Dr Heatley and me to go to America in 1941, to enlist their aid At the same time it appeared essential that work on the chemical side should be pushed on with all speed, in the hope that penicillin might be relatively easy to synthesise, so that we could dispense with the laborious method of production by cultivation of the mould and extraction from the metabolism fluid

I have not time unfortunately to speak of all that went on

in America, but it is sufficient to say that Dr. Coghill and his colleagues at the Government Agricultural Laboratory at Peoria, by two first-class contributions, have really made production on a large scale possible, since both have greatly increased the yield obtained in culture. Firstly they discovered strains of *Penicillium notatum* which are better producers of penicillin than the original strain and, secondly, what is more important, they have greatly improved the culture medium, so that at the present time the yields of penicillin per cubic centimetre of brew are from 100 to 150 times greater than those we first obtained at Oxford. In addition, greatly improved methods for culture have been devised in America both by the Peoria workers and by commerical firms. At the same time, even under the difficult conditions of war-time, production has been greatly expanded in England. With the ever-increasing amounts produced, more and more clinical experience is being obtained, and at the same time great progress has been made in the chemical examination of the material. I am afraid I am not at liberty to discuss the chemical work, but I may say that there are at least 3 chemically different kinds of penicillin.

At the present time very active exploration is going on of the antibacterial substances produced by many moulds. There is time only to mention these and to call your attention to a renewed interest in the group of organisms known as actinomycetes, which were first explored from this point of view by Lieske and by Gratia and Dath. They are very common in soil and in the air. One of them produces a substance called streptomycin which has chemotherapeutic possibilities. It is probably more poisonous than penicillin but it is active against some bacteria which penicillin does not affect. The exploration of this vast field of antibiosis, with all the biochemical and other experimental techniques now at our disposal, promises to throw much light on the mode of action of bacteria, and also holds promise that we may learn sufficient to find or make compounds which will be effective against most, if not all, bacterial diseases.

PROCEEDINGS OF THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

Obituary.

WALTER LLEWELLYN BULLOCK.

Born, March 7th, 1890. *Died, February 19th,* 1944.

W. Ll. Bullock, who was a member of the Society's Council, was born in London and educated first at Liverpool College and then, from 14 to 19, at Rugby, which he left in 1909 for an unconventional change of scene which laid the foundation of his wide and varied experience. He went to the United States and became for five years a metallurgical chemist in a large Chicago malleable iron foundry. During these years he took up a course of training at a dramatic school; later, while at Harvard, he had some experience of the professional stage and a successful career would have been open to him in that field, a fact which will not surprise those who knew his love of the drama and his remarkable gifts as an actor. However, the world of scholarship attracted him more strongly. He entered Harvard in 1913 and took both B.A. and M.A. there in 1917, but again he left conventional paths, this time to go on a Harvard mission to Russia and Roumania. Returning to America in 1919, he married the next year, and took his Ph.D. in Romance Languages at Harvard in 1922. He had begun by specialising in Old French, but by this time the Italian field had claimed him; he had taken up his specialist studies in the Cinquecento, and had begun to collect that valuable library of sixteenth-century Italian books which is now in the Library of Manchester University.

In 1922 he was appointed Assistant Professor of Italian at Bryn Mawr College, and in 1927, Associate Professor in the University of Chicago, in what was then considered the best Romance Department in the United States. His energetic, varied and faithful services to Italian culture in America

won him the Order of *Cavaliere della Corona d'Italia* in 1933.

He came to England in 1935 to occupy the Chair of Italian Studies at Manchester University. Not daunted by the difficulties of a time most unpropitious for the promotion of Italian Studies, he quickly got into touch with small groups and societies up and down the country who were interested in the study of Italian ; he kept the Manchester Dante Society alive ; and founded just before the war a quarterly review called *Italian Studies* Meanwhile, his home was a welcoming centre for all those in the local community to whom Italy had a real meaning.

During these years he had ceaselessly endeavoured to interpret Italy to the public by means of Extension Lectures ; and sometimes America too was the subject of his talks His life had been equally shared between the States and England ; knowledge, experience, wide and genial sympathies all gave him exceptional qualification as the interpreter of the one nation to the other. Work of this kind carried out among the armed Forces was his signal contribution to the war effort, a contribution all the more valuable, among the passions of war time, by virtue of his strong sense of European values, and of the common humanity of all peoples, his firm but tolerant mind. To these labours he gave indeed too much of physical energy and health. He was still working on his edition of Tasso's *Aminta,* on a book about Ferrara, and an Italian-English dictionary ; and was carrying a greater burden than his colleagues knew or than even his unflagging energy could support. He died suddenly on February 19th, 1944, after returning from one of his lectures to the Forces. The loss to Italian Studies in England was very great indeed, but greater still was the loss to us all of his great, generous, and candid spirit.

PROCEEDINGS.

1943—1944.

Eight ORDINARY MEETINGS were held during the session, at which lectures were delivered as follows :

1943.

Oct. 5th. "Agricultural Reconstruction in Europe after the War", by Sir JOHN RUSSELL.

Oct. 19th. "The Nature and Purpose of Art and its place in the Community", by Canon PETER GREEN. (Published *Memoir* 2, vol. lxxxvi.)

Nov. 2nd. "Captain Thomas Brown, Curator of the old Manchester Museum", by Dr. J. W. JACKSON. (Published *Memoir* 1, vol. lxxxvi.)

Nov. 19th. "The Electron Microscope", by Dr. H. HUNTER. Joint Meeting with Manchester Scientific Societies, arranged by the Society of Dyers and Colorists.

1944.

Jan. 18th. "The Anatomical Localisation of the Soul (Mind), 1640—1940" by Professor GEOFFREY JEFFERSON.

Feb. 1st. "Some evidence of Ritual Worship in Neolithic Times, from a Norfolk flint mine excavation", by A. L. ARMSTRONG, Esq.

Feb. 29th. "Geological Time", by Dr. E. C. BULLARD. Joint Meeting with the Physical Society of Manchester and the Geographical Association. (Published *Memoir* 4, vol. lxxxvi.)

Mar. 7th. "Asoka, the Philosopher Emperor", by P. D. MEHTA, Esq. (Published *Memoir* 3, vol. lxxxvi.)

The ANNUAL GENERAL MEETING was held on Tuesday, May 23rd, 1944, in the Council Chamber of the Manchester College of Technology.

PROCEEDINGS.

1944—1945.

Five ORDINARY MEETINGS were held during the session, at which lectures were delivered as follows :

1944.	
Oct. 10th.	"John Dalton and Manchester", by Rev. H. McLACHLAN. (Published *Memoir* 7, vol. lxxxvi.)
	"The Atomic Theory", by Professor A. D. RITCHIE. (Published *Memoir* 8, vol. lxxxvi.)
Nov. 14th.	"Science and the Modern Crisis", by Professor M. POLANYI. (Published *Memoir* 6, vol. lxxxvi.)
Dec. 12th.	"Some Biological Problems of English Lakes and Meres", by Dr. E. M. LIND. (Published *Memoir* 5, vol. lxxxvi.)
1945.	
Jan. 16th.	"Some Antibiotics, with special reference to Penicillin", by Professor H. W. FLOREY. (Wilde Memorial Lecture.) (Published *Memoir* 9, vol. lxxxvi.)
Feb. 13th.	"The Libyan Desert in Peace and War", by Brigadier R. A. BAGNOLD.

The ANNUAL GENERAL MEETING was held on Wednesday, July 4th, 1945, in the Council Chamber of the Manchester College of Technology.

ANNUAL REPORT OF THE COUNCIL, APRIL, 1944

Membership.

During the session 1943–1944 eight new members were elected, bringing the total up to 164 including 11 Life Members. There were nine resignations during the session. The Council regrets to record the deaths of two Ordinary Members: Mr. W. F. Higgins and Dr. C. W. Soutar; one Life Member: Mr. H. J. Woodall; and one member of the Council: Professor W. Ll. Bullock.

Meetings.

Details of meetings will be found in the Proceedings. Eight lectures were delivered and a joint meeting was held with Manchester scientific societies. The average attendance was fifty. The Council regrets that the Wilde Memorial Lecture had to be cancelled owing to Professor Florey's absence abroad on Government business.

Three Council meetings have been held, at which much attention has been paid to plans for the Society's future home. A special Council Meeting was devoted entirely to discussion of library policy.

On behalf of the Society the Council tenders its thanks to the authorities of the University of Manchester for their kindness in allowing the use of their rooms for lectures and Council Meetings.

Accounts.

An audited financial statement is attached, together with particulars of assets and liabilities.

Gifts.

The Council expresses the Society's thanks to the donors of the following gifts:

"The Quarterly Journal of the Royal Meteorological Society", presented by Dr. J. R. Ashworth. "Transactions and Proceedings of the Royal Entomological Society of London", presented by Major A. W. Boyd. "A Centenary History of the Manchester Medical Society". "The Founda-

tion of Provincial Medical Education in England". "The Book of Manchester and Salford". "The Honorary Medical Staff of the Manchester Infirmary, 1752—1830. "A Medical Statistician of a century and a half ago". "The Manchester Medical Society and the Literary and Philosophical Society of Manchester". "John Dalton", presented by Dr. E. M. Brockbank. *Memoirs*, Vol. 5, Part II, presented by Mr. D. M. Henshaw. *Memoirs*, Vol. 4, Part I and Vol 5, Part I, presented by the Rev. H. W. Dickinson through Mr. G. W. Cussons. *Memoirs*, Vol. 15, second series, 1860; Vol. 2, third series, 1865; Vol. 3, third series, 1868 (2 copies). *Memoirs and Proceedings*, Vol. 7, fourth series, 1893; Vol 9, fourth series, 1895; Vol. 47, 1902-3; Vol. 58, 1913-14; Vol. 59, 1914-15", presented by Dr. W. H. Taylor. "Verses on the Sign of the Zodiac", presented by Mr. F. W. Whaley.

Gifts of back numbers of the *Memoirs and Proceedings* will be welcomed. Since the destruction of the library the Society has not been able to make a complete set.

Air Raid Loss.

The valuation of the library by Messrs. Wm. Dawson and Sons Ltd., licenced valuers of London, has been considered by the Board of Trade, but no further progress in the direction of a settlement has been made because the Council considers the sum offered quite inadequate. The Society's solicitor, Sir John Taylor, is still pursuing the matter, and hopes that a decision may be reached within the next few months.

The claim for the loss of the house is not yet due for consideration by the War Damage authorities because property in the class "Not completely destroyed" has priority.

NOTE.—The Treasurer's Accounts of the Session 1943—1944 have been endorsed as follows :

April 1944, Audited and found correct.

We have seen the Banker's certificate that they hold £375 of 3½ % War Loan Stock :—£300 of 3½ % War Stock : 1 Bond for £50 and a Bond for £25 3½ % War Loan 1929–47 Inscribed Stock ; and £800 3 % War Stock 1955—1959 ; and Bond Book for £250 3 % Defence Bonds ; and the Certificates of the following stocks :—£1,225 Great Western Railway Company's 5 % Consolidated Preference Stock, Nos. 31,794, 31,792, and 31,796 ; £7,500 Gas, Light and Coke Company Ordinary Stock (Nos. 340,891 and 347,456) ; £100 East India Railway Company £4. 10s. % Annuity Class A Stock (No. 25,656) ; £700 4 % Funding Stock, 1960—1990, Nos. 34,185 and 23/3,457 ; and the deeds of the Natural History Fund, of the Wilde Endowment Fund, those conveying land on which the Societies' premises stood, and the Declarations of Trust.

Leases and Conveyances dated as follows :—

September 22nd, 1797.
September 23rd, 1797.
December 25th, 1799.
December 25th, 1799.
December 23rd, 1820.
December 23rd, 1820.

Declarations of Trust :—

June 24th, 1801.
December 23rd, 1820.
January 8th, 1878.

The certificate for the Dalton and other Medals of the Society.

We have verified the balances of the various accounts with the banker's pass books.

(*Signed*) J. M. NUTTALL.
A. C. ALEXANDER.

April 21st, 1944.

MANCHESTER LITERARY

R. H. Clayton, Treasurer, in Account with the

GENERAL

	£	s.	d.	£	s.	d.
To Balance at Bank, April 1st, 1943				88	11	0
,, Cash in Treasurer's Hands, April 1st, 1943...				5	4	11
,, Members' Subscriptions :—						
Full Rate. Arrears	21	0	0			
,, ,, 1943–44...	131	5	0			
				152	5	0
,, Dividends :—						
Great Western Railway Company's 5 % Consolidated Preference Stock	30	12	6			
East India Railway Company's 4½ % Annuity Class A	3	13	10			
£300 3½ % War Stock	10	10	0			
£75 3½ % War Loan	2	12	6			
£250 Defence Bonds	1	12	5			
				49	1	3
,, Sales of Publications				22	13	2
,, Endowment :—						
Sir Joseph Larmor, Deceased Amount received by the Society... ...				250	0	0
,, Transfer from Building Fund...				100	0	0
,, Bank Interest					9	8
				£668	5	[illegible]

AND PHILOSOPHICAL SOCIETY.

Society, from April 1st, 1943, to March 31st, 1944.

FUND.

	£	s.	d.	£	s.	d
By Charges on Property :— Chief Rent (Net) and Income Tax Schedule "A"				12	18	2
,, Office Expenses				13	0	0
,, Administrative Charges :—						
State Insurance	4	17	2			
Employers' Liability Insurance		4	6			
Telephone	2	9	5			
Postage and Carriage	12	7	2			
Printing and Stationery	39	19	5			
Lecturers' Expenses	25	0	0			
Legal Expenses	9	12	0			
Miscellaneous Expenses	6	17	7			
				101	7	3
,, Printing Memoirs and Proceedings, 1941–43				219	6	0
,, Purchases of Books...				1	16	0
,, Amount invested in 3 % Defence Bonds being the amount received by the Society in connection with the Sir Joseph Larmor Endowment...				250	0	0
,, Subscription to Portico Library				5	0	0
,, Proportion of Expenses of Joint Lecture with the Society of Dyers and Colourists				1	4	11
,, Subscriptions to Societies :—						
Palæontographical Society	1	1	0			
Malacological Society	1	10	0			
Ray Society	1	1	0			
North-Western Naturalists' Union ...		14	0			
Prehistoric Society		15	0			
				5	1	0
,, Bank Postages					2	11
,, Cash in Treasurer's Hands				8	15	8
,, Balance at Bank				49	13	1
				£668	5	0

WILDE ENDOWMENT FUND, 1943–44.

	£	s.	d.		£	s.	d.
To Balance at Bank, April 1st, 1943	236	6	8	By Salaries, etc.	142	6	8
,, Cash in Treasurer's hands	10	0	0	,, Cash in Treasurer's hands	2	13	4
,, Dividend on £7,500 Gas, Light and Coke Company's Ordinary Stock	56	0	0	,, Cash at Bank, March 31st, 1942	164	2	8
,, Interest on £400 3 % War Stock 1955–59	6	0	0				
,, Bank Interest		11	0				
	£309	2	8		£309	2	8

BUILDING FUND 1943–44.

	£	s.	d.		£	s.	d.
To Balance at Bank, April 1st, 1943	176	18	8	By Cash Transfer to General Fund	100	0	0
,, Interest on £700 Funding Loan 4 % Stock	28	0	0	,, Balance at Bank	111	7	9
,, Interest on £400 3 % War Stock, 1955–59	6	0	0				
,, Bank Interest		9	1				
	£211	7	9		£211	7	9

JOULE MEMORIAL FUND, 1943–44. (Included in the General Account.)

	£	s	d		£	s.	d.
To Dividend on £100 East India Railway Company's 4½ % Annuity Class A Stock	3	13	10	By Cash transferred to General Fund	14	3	10
,, Interest on £300 3½ % War Stock	10	10	0				
	£14	3	10		£14	3	10

NATURAL HISTORY FUND, 1943–44. (Included in the General Account.)

	£	s.	d		£	s.	d.
To Dividend on £1,225 Great Western Railway Company's 5 % Consolidated Preference Stock	30	12	6	By Cash transferred to General Fund	30	12	6
	£30	12	6		£30	12	6

SIR JOSEPH LARMOR FUND, 1943–44. (Included in the General Account.)

	£	s	d		£	s.	d.
To Interest on £250 Defence Bonds	1	12	5	By Cash Transferred to General Fund	1	12	5
	£1	12	5		£1	12	5

Statement relating to the Society's Property as on March 31st, 1944.

LIABILITIES.	£ s. d	ASSETS.	£ s. d	£ s. d.
		Arrears of Subscriptions, 1940–44	37 16 0	
		,, ,, 1942–44	8 8 0	
		,, ,, 1943–44	9 9 0	
				55 13 0
		Cash Balance :—		
		In Bank, Building Fund	111 7 9	
		,, ,, Wilde Fund	164 2 8	
		,, ,, General Fund	49 13 1	
		,, Treasurer's hands...	11 9 0	
				336 12 6
				£392 5 6

Investments :—

£7,500 Gas, Light and Coke Company's Ordinary Stock (W.E.F.) ... ...
£400 3 % War Stock, 1955—1959 (W.E.F.) .. ..
£700 4 % Funding Loan (B.F.) ... ...
£400 3 % War Stock, 1955—1959 (B.F.) ... ...
£100 East India Railway Company's 4½ % Annuity Class A (J.M.F.) ... ...
£300 3½ % War Stock (J.M.F.)... ... ...
£1,225 Great Western Railway Company's 5 % Consolidated Preference Stock (Nat. Hist. F.) ... ...
£75 3½ % War Loan Stock, 1929–47 (G.F.) ... ...
£250 Defence Bonds (Sir J. Larmor F.) ... ...

A claim for repayment of Income Tax 1942–43 has been submitted to the Inland Revenue for £80 19 0

J. M. NUTTALL.

April 21st, 1944. A. C. ALEXANDER.

ANNUAL REPORT OF THE COUNCIL, MAY, 1945.

Membership.

During the session 1944–45, eight new members were elected, bringing the total up to 160, including 13 Life Members. There were 11 resignations during the session.

The Council regrets to record the death of one Ordinary Member, Sir Christopher T. Needham.

Meetings.

The Annual General Meeting was held in the Council Chamber of the Manchester College of Technology on May, 23rd, 1944, when Professor M. Polanyi was elected President of the Society.

On October 10th, 1944, the Society held the John Dalton Memorial Lecture in the Main Lecture Theatre of the Central Library, St. Peter's Square, Manchester, to commemorate the centenary of John Dalton's death. The Memorial Lecture was given by Professor A. D. Ritchie, who chose as his title "The Atomic Theory", and the lecture was preceded by an address given by the Reverend Dr. H. McLachlan on "John Dalton and Manchester". The President of the Society took the chair, and among the official guests who conveyed special messages were the Lord Mayor of Manchester (Alderman Leonard B. Cox, J.P.), Dr. Masson, representing the Royal Society, London, Professor J. Hadamard, representing the Academy of Sciences, Paris, Dr. A. P. M. Fleming, representing the British Association.

The proceedings were recorded by the B.B.C.

The Wilde Memorial Lecture was held on March 13th, 1945, in the Main Lecture Theatre of the Chemistry Department of the University of Manchester, and was given by Sir Howard Florey, F.R.S., who spoke on "Some Antibiotics with special reference to Penicillin".

Professor M. Polanyi delivered his Presidential Address on "Science and the Modern Crisis" on November 14th, 1944, in the Reynolds Hall, Manchester College of Technology.

Professor Dobree, Miss Emmett and Professor A. D. Ritchie contributed to the discussion on the invitation of the President.

A similar discussion meeting on "The Unity of Knowledge" was given by Professor the Reverend T. W. Manson on January 12th, 1945, in the Reynolds Hall, and Mr. G. A. Sutherland and Mr. R. D. Waller contributed to the discussion on the invitation of the President.

Dr. E. M. Lind addressed the Society on December 12th, 1944, on "Some Biological Problems of English Lakes and Meres", and on February 13th, 1945, Brigadier R. A. Bagnold, F.R.S., gave a lecture on "The Libyan Desert in Peace and War".

Council Meetings.

Five Council Meetings have been held during the session at which much consideration has been given to the future policy of the Society.

The Council appointed a sub-committee to consider the President's proposal for an Annual Lecture in conjunction with the University of Manchester, and the recommendations of that sub-committee were adopted by Council.

On behalf of the Society the Council tenders its thanks to the authorities of the University of Manchester and the Manchester College of Technology for their kindness in allowing the use of their rooms for lectures and Council Meetings.

Accounts.

An audited financial statement is attached, together with particulars of assets and liabilities

Gifts.

The Council expresses the Society's thanks to the donors of the following gifts :

Memoirs and Proceedings—Vol. 3, 2nd Series, part, "Tribute to the Memory of Stanley Percival", from Saint John's College, Cambridge; Vol. 63, Part I, from Mrs. Palmer; Vols. 74 to 77, from Professor W. E. Morton; Vols. 79 and 81, from Miss C. M. Legge; Vol. 81, part III, from Miss C. M. Legge; Vols. 81 and 83, from Major A. W. Boyd.

Various parts of the Royal Entomological Society's publications from Major A. W. Boyd; A copy of "Paris's Life of Sir Humfrey Davy", from Capt. Edgar C. Smith; Miniature of John Dalton, from Mr. E. Goodhew; a daguerrotype of John Dalton and a letter written by him, from Miss Law, large portrait engraving of John Dalton, in frame, from Mr. H. Hampson; small portrait engraving of John Dalton, in frame, from Miss Rooke; a quarter plate photo of John Dalton's grave, from Dr. Ashworth; a thermometer, used by John Dalton, from Mrs. Katherine Smithells, on behalf of her late husband, Professor Arthur Smithells; a photograph of a certificate, given by John Dalton to one of his students, from Mr. J. H. Walmsley of Messrs. James Woolley and Sons, through Dr. F. C. Toy; a copy of Dalton's "Meteorology", from Miss Kate Dornan, a microscope with mahogany stand and reflector and a copy of Mr. Henry Sidebottom's book on the "Foraminifera of the Island of Delos", from the family of the late Mr. Henry Sidebottom.

Gifts of back numbers of the Memoirs and Proceedings will be welcomed. Since the destruction of the library the Society has not been able to make a complete set.

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April, 1945, Audited and found correct.

We have seen the Banker's certificate that they hold £375 of 3½ % War Loan Stock :—£300 of 3½ % War Stock : 1 Bond for £50 and a Bond for £25 War Loan 1929-47 Inscribed Stock : and £800 3 % War Stock 1955—1959 : and Bond Book for £250 3 % Defence Bonds : and the certificates of the following Stocks :—£1,225 Great Western Railway Company's 5 % Consolidated Preference Stock, Nos. 31794, 31792 and 31796. £7,500 Gas, Light and Coke Company Ordinary Stock (Nos. 340891 and 347456) ; £100 East India Railway Company £4. 10s. % Annuity Class A Stock (No 25,656) ; £700 4 % Funding Stock, 1960—1990, Nos. 34,185 and 23/3,457, and the deeds of the Natural History Fund, of the Wilde Endowment Fund, those conveying land on which the Society's premises stood, and the Declarations of Trust.

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September 23rd, 1797.
December 25th, 1799.
December 25th, 1799.
December 23rd, 1820.
December 23rd, 1820.

Declarations of Trust :—

June 24th, 1801.
December 23rd, 1820.
January 8th, 1878.

Documents relating to the sale of 21, Back George Street by the Honourable Violet Frances St. Clair to the Society.

The certificate for the Dalton and other Medals of the Society.

We have verified the balances of the various accounts with the banker's pass books.

(*Signed*) HY. S. LAND,
W. H. BRINDLEY.

May 16th, 1945.

MANCHESTER LITERARY

R. H. Clayton, Treasurer, in Account with the

GENERAL

	£ s d	£ s d
To Balance at Bank, April 1st, 1944		49 13 1
,, Cash in Treasurer's Hands, April 1st, 1944		8 15 8
,, Members' Subscriptions —		
Full Rate Arrears	16 16 0	
,, ,, 1944–45	163 4 0	
		180 0 0
Dividends —		
Great Western Railway Company's 5 % Consolidated Preference Stock	30 12 6	
East India Railway Company's 4½ % Annuity Class A	3 15 0	
£300 3½ % War Stock	10 10 0	
£75 3½ % War Loan	2 12 6	
£250 Defence Bonds	7 10 0	
		55 0 0
Sales of Publications		12 6 10
Gift from Lord McGowan as Chairman of the I C I, through Dr Ashworth for reproduction of portrait of John Dalton		50 0 0
Refund of Income Tax, 1942-43		37 9 0
,, ,, ,, ,, 1943-44		37 7 9
Bank Interest		9 5
		£431 1 9

AND PHILOSOPHICAL SOCIETY.

Society, from April 1st, 1944, to March 31st, 1945.

FUND.

	£	s.	d.	£	s.	d.
By Charges on Property :—						
Chief Rent (Net) and Income Tax Sch "D"	12	18	2			
,, Office Expenses	13	5	0			
				26	3	2
,, Administrative Charges :—						
State Insurance...	4	8	0			
Employers' Liability Insurance		4	6			
Telephone	2	7	1			
Printing and Stationery	47	8	11			
Lecturers' Expenses	11	19	0			
Postage and Carriage	14	7	8			
Miscellaneous Expenses	20	0	11½			
				100	16	1½
,, Purchases of Books				2	2	6
,, Building Valuation (J. R. Bridgford & Son)				15	15	0
,, Subscriptions to Societies :—						
North-Western Naturalists' Union...		14	0			
Ray Society	1	1	0			
Pre-historic Society		15	0			
Palæontographical Society	1	1	0			
Malacological Society	1	10	0			
Royal Entomological Society of London subscription and arrears	6	6	0			
				11	7	0
,, Bank Charges and Cheque Book					11	1
,, Cash in Treasurer's Hands				1	14	3½
,, Balance at Bank				272	12	7
				£431	1	9

WILDE ENDOWMENT FUND, 1944–45.

	£ s d		£ s d
To Balance at Bank, April 1st, 1944	164 2 8	By Salaries etc	150 0 0
,, Cash in Treasurer's Hands	2 13 4	,, Cash in Treasurer's hands	7 13 4
,, Dividend on £7,500 Gas Light and Coke Company's Ordinary Stock	187 10 0	,, Cash at Bank	402 14 5
,, Interest on £400 3 % War Stock 1955—1959	6 0 0		
,, Income Tax refunded 1942–43 and 1943-44	199 10 0		
,, Bank Interest	11 9		
	£560 7 9		£560 7 9

BUILDING FUND, 1944–45.

	£ s d		£ s d
To Balance at Bank, April 1st, 1944	111 7 9	By Balance at Bank April 1st 1945	148 14 11
,, Interest on £700 Funding Loan 4 %	28 0 0		
,, Interest on £400 3 % War Stock 1955–59	9 0 0		
,, Bank Interest	7 2		
	£148 14 11		£148 14 11

JOULE MEMORIAL FUND, 1944–45. (Included in the General Account.)

	£ s d		£ s d.
To Dividend on £100 East India Railway Company's 4½ % Annuity Class A Stock	3 15 0	By Cash transferred to General Fund	14 5 0
,, Interest on £300 3½ % War Stock	10 10 0		
	£14 5 0		£14 5 0

NATURAL HISTORY FUND, 1944–45. (Included in the General Account.)

	£ s d		£ s. d.
To Dividend on £1,225 Great Western Railway Company's 5 % Consolidated Preference Stock	30 12 6	By Cash transferred to General Fund	30 12 6
	£30 12 6		£30 12 6

SIR JOSEPH LARMOR FUND, 1944–45. (Included in the General Account.)

	£ s d		£ s d
To Interest on £250 Defence Bonds	7 10 0	By Cash transferred to General Fund	7 10 0
	£7 10 0		£7 10 0

Statement relating to the Society's Property as on March 31st, 1945.

Liabilities.	£	s.	d.	Assets.	£	s.	d.	£	s.	d.
				Arrears of Subscriptions, 1940–45	10	10	0			
				,, ,, 1942–45	9	9	0			
				,, ,, 1943–45	8	8	0			
				,, ,, 1944–45	5	5	0			
								33	12	0
				Cash Balance :—						
				In Bank, Building Fund...	148	14	11			
				,, ,, Wilde Fund	402	14	5			
				,, ,, General Fund	272	12	7			
				In Treasurer's hands...	9	7	7½			
								833	9	6½
								£867	1	6½
				Investments :—						
				£7,500 Gas Light & Coke Company's Ordinary Stock (W.E.F.)						
				£400 3 % War Stock, 1955—1959 (W.E.F.)						
				£700 4 % Funding Loan (B.F.)						
				£400 3 % War Stock, 1955—1959 (B.F.)						
				£100 East India Railway Company's 4½ % Annuity Class A (J.M.F.)						
				£300 3½ % War Stock (J.M.F.)						
				£1,225 Great Western Railway Company's 5 % Consolidated Preference Stock (Nat. Hist. F.)						
				£75 3½ % War Loan Stock, 1929–47 (G.F.)						
				£250 Defence Bonds (Sir J. Larmor F.)...						

THE WILDE LECTURES.

1897. (July 2.) "On the Nature of the Röntgen Rays." By Sir G. G. STOKES, Bart., F.R.S.

1898. (Mar. 29.) "On the Physical Basis of Psychical Events." By Sir MICHAEL FOSTER, K.C.B., F.R.S.

1899. (Mar. 28.) "The newly-discovered Elements; and their relation to the Kinetic Theory of Gases." By Professor WILLIAM RAMSAY, F.R.S.

1900. (Feb. 13.) "The Mechanical Principles of Flight." By the Rt. Hon. LORD RAYLEIGH, F.R.S.

1901. (April 22.) "Sur la Flore du Corps Humain." By Dr. ELIE METCHNIKOFF, For. Mem.R.S.

1902. (Feb. 25.) "On the Evolution of the Mental Faculties in relation to some Fundamental Principles of Motion." By Dr HENRY WILDE, F.R.S.

1903. (May 19.) "The Atomic Theory." By Professor F. W. CLARKE, D.Sc.

1904. (Feb. 23.) "The Evolution of Matter as revealed by the Radio-active Elements." By FREDERICK SODDY, M.A.

1905. (Feb. 28.) "The Early History of Seed-bearing Plants, as recorded in the Carboniferous Flora." Dr. D. H. SCOTT, F.R.S.

1906. (March 20.) "Total Solar Eclipses." By Professor H. H. TURNER, D.Sc., F.R.S.

1907. (Feb. 18.) "The Structure of Metals." By Dr. J. A. EWING, F.R.S., M.Inst.C.E.

1908. (March 3.) "On the Physical Aspect of the Atomic Theory." By Professor J. LARMOR, Sec.R.S.

1909. (Mar. 9.) "On the Influence of Moisture on Chemical Change in Gases." By Dr. H. BRERETON BAKER, F.R.S.

1910. (Mar. 22.) "Recent Contributions to Theories regarding the Internal Structure of the Earth." By Sir THOMAS H. HOLLAND, K.C.I.E., D.Sc., F.R.S.

SPECIAL LECTURES.

1913. (Mar. 4.) "The Plant and the Soil." By A. D. HALL, M.A., F.R.S.

1914. (Mar. 18.) "Crystalline Structure as revealed by X-rays." By Professor W. H. BRAGG, M.A., F.R.S.

1915. (May 4.) "The Place of Science in History." By Professor JULIUS MACLEOD, D.Sc.

DALTON MEMORIAL LECTURES.

1931. (Mar. 17.) "Atoms and Electrons." By Sir JOSEPH J. THOMSON, O.M., D.Sc., F.R.S.

1944. (Oct. 10.) "The Atomic Theory." By Professor A. D. RITCHIE.

JOULE MEMORIAL LECTURES.

1920. (Dec. 14.) "The Work and Discoveries of Joule." By Sir DUGALD CLERK, K.B.E., D.Sc., F.R.S.

1922. (Dec. 5.) "The Rise in Motive Power and the Work of Joule." By Sir CHARLES A. PARSONS, O.M., K.C.B., M.A., D.Sc., F.R.S.

1924. (Mar. 4.) "Thermodynamics in Physiology." By A. V. HILL, O.B.E., M.A., Sc.D., F.R.S.

1928. (Mar. 20.) "Sub-Atomic Energy." By Professor A. S. EDDINGTON, M.A., D.Sc., LL.D., F.R.S.

1930. (Feb. 18.) "Science and Problems of the Times." By A. P. M. FLEMING, C.B.E., M.Sc., M.I.E.E.

1933. (Mar. 14.) "The Psychology of Musical Appreciation." By CHARLES S. MYERS, C.B.E., F.R.S.

1934. (Feb. 27.) "The Expanding Universe as a Thermodynamic System." By Professor E. A. MILNE, M.A., D.Sc., F.R.S.

1936. (Feb. 11.) "The Upper Atmosphere." By Professor E. V. APPLETON, M.A., D.Sc., LL.D., F.R.S.

1938. (Mar. 8.) "The Attainment of Low Temperature." By Dr. C. G. DARWIN, M.C., M.A., F.R.S.

1940. (Mar. 19.) "New Applications of Physics to Medici[illegible]" By Professor JAS. CHADWICK, F.R.S.

1942. (Nov. 10.) "Man and the Weather." By Professor DAVID BRUNT, F.R.S., M.A., Sc.D.

WILDE MEMORIAL LECTURES.

1926. (Mar. 9.) "Brains of Apes and Men." By G. ELLIOT SMITH, M.A., M.D., F.R.S.
1927. (Mar. 22.) "Physiology of Life in the High Andes." By J. BARCROFT, C.B.E., F.R.S.
1929. (Mar. 19.) "The Nature and Origin of Human Speech." By Sir RICHARD PAGET, Bart.
1932. (Mar. 15.) "Man's Place in Nature as shown by Fossils." By Sir ARTHUR SMITH-WOODWARD, LL.D., F.R.S.
1935. (Feb. 12.) "Some Sex Problems in the Fungi." By Professor Dame HELEN GWYNNE VAUGHAN, G.B.E., LL.D., D.Sc., F.L.S.
1937. (Feb. 16.) "Some Problems of the New Stone Age." By HAROLD J. E. PEAKE, M.A., F.S.A.
1939. (Mar. 14.) "Palæolithic Man in the North Midlands." By LESLIE ARMSTRONG, M.C., F.S.I., F.S.A.
1941. (Apr. 29.) "A New Era in Medicinal Treatment." By Sir HENRY H. DALE, President of the Royal Society.
1945. (Mar. 13.) "Some Antibiotics with Special Reference to Penicillin." By Sir HOWARD FLOREY, F.R.S.

Awards of the Dalton Medal.

1898. EDWARD SCHUNCK, Ph.D., F.R.S.
1900. Sir HENRY E. ROSCOE, F.R.S.
1903. Professor OSBORNE REYNOLDS, LL.D., F.R.S.
1919. Professor Sir ERNEST RUTHERFORD, M.A., D.Sc., F.R.S.
1931. Sir JOSEPH J. THOMSON, O.M., D.Sc., F.R.S.
1942. Sir LAWRENCE BRAGG, O.B.E., M.C., F.R.S., D.S.C., M.A.

A detailed list of the medals, awarded to John Dalton and others, which are the property of the Society, will be found in Memoirs and Proceedings, Vol. 84, 1939–41, *pp.* xxxi—xxxiii.

A DETAILED LIST OF ARTICLES SALVAGED FROM 36, GEORGE STREET, MANCHESTER, AFTER THE DESTRUCTION OF THE BUILDING ON DECEMBER 24TH, 1940, WILL BE FOUND IN *Memoirs and Proceedings*, VOL. 84, 1939–41, *pp.* xxxiv—xxxvii.

LIST OF PRESIDENTS OF THE SOCIETY.

Date of Election.	
1781.	PETER MAINWARING, M.D., JAMES MASSEY.
1782–1786.	JAMES MASSEY, THOMAS PERCIVAL, M.D., F.R.S.
1787–1789.	JAMES MASSEY.
1789–1804.	THOMAS PERCIVAL, M.D., F.R.S.
1805–1806.	REV. GEORGE WALKER, F.R.S.
1807–1809.	THOMAS HENRY, F.R.S.
1809.	*JOHN HULL, M.D., F.L.S.
1809–1816.	THOMAS HENRY, F.R.S.
1816–1844.	JOHN DALTON, D.C.L., F.R.S.
1844–1847.	EDWARD HOLME, M.D., F.L.S.
1848–1850.	EATON HODGKINSON, F.R.S., F.G.S.
1851–1854.	JOHN MOORE, F.L.S.
1855–1859.	SIR WILLIAM FAIRBAIRN, Bart., LL.D., F.R.S.
1860–1861.	JAMES PRESCOTT JOULE, D.C.L., F.R.S.
1862–1863.	EDWARD WILLIAM BINNEY, F.R.S., F.G.S.
1864–1865.	ROBERT ANGUS SMITH, Ph.D., F.R.S.
1866–1867.	EDWARD SCHUNCK, Ph.D., F.R.S.
1868–1869.	JAMES PRESCOTT JOULE, D.C.L., F.R.S.
1870–1871.	EDWARD WILLIAM BINNEY, F.R.S., F.G.S.
1872–1873.	JAMES PRESCOTT JOULE, D.C.L., F.R.S.
1874–1875.	EDWARD SCHUNCK, Ph.D., F.R.S.
1876–1877.	EDWARD WILLIAM BINNEY, F.R.S., F.G.S.
1878–1879.	JAMES PRESCOTT JOULE, D.C.L., F.R.S.
1880–1881.	EDWARD WILLIAM BINNEY, F.R.S., F.G.S.
1882–1883.	SIR HENRY ENFIELD ROSCOE, D.C.L., F.R.S.
1884–1885.	WILLIAM CRAWFORD WILLIAMSON, LL.D., F.R.S.
1886.	ROBERT DUKINFIELD DARBISHIRE, B.A., F.G.S.
1887.	BALFOUR STEWART, LL.D., F.R.S.
1888–1889.	OSBORNE REYNOLDS, LL.D., F.R.S.
1890–1891.	EDWARD SCHUNCK, Ph.D., F.R.S.

* Elected April 28th; resigned office May 5th.

Date of Election.

1892–1893. ARTHUR SCHUSTER, Ph.D., F.R.S.
1894–1896. HENRY WILDE, D.C.L., F.R.S.
1896. EDWARD SCHUNCK, Ph.D., F.R.S.
1897–1899. JAMES COSMO MELVILL, M.A., F.L.S.
1899–1901. HORACE LAMB, M.A., F.R.S.
1901–1903. CHARLES BAILEY, M.Sc., F.L.S.
1903–1905. W. BOYD DAWKINS, M.A., D.Sc., F.R.S.
1905–1907. SIR WILLIAM H. BAILEY, M.I.Mech.E.
1907–1909. HAROLD BAILY DIXON, M.A., F.R.S.
1909–1911. FRANCIS JONES, M.Sc., F.R.S.E.
1911–1913. F. E. WEISS, D.Sc., F.L.S.
1913–1915. FRANCIS NICHOLSON, F.Z.S.
1915–1917. SYDNEY J. HICKSON, M.A., D.Sc., F.R.S.
1917–1919. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C.
1919. G. ELLIOT SMITH, M.A., M.D., F.R.S.
1919–1921. SIR HENRY A. MIERS, M.A., D.Sc., F.R.S.
1921–1923. T. A. COWARD, M.Sc., F.Z.S., F.E.S.
1923–1925. H. B. DIXON, C.B.E., M.A., Ph.D., M.Sc., F.R.S., F.C.S.
*1925. REV. A. L. CORTIE, S.J., D.Sc., F.R.A.S., F.Inst.P.
1925–1927. H. LEVINSTEIN, D.Sc., M.Sc., F.I.C.
1927–1929. W. L. BRAGG, O.B.E., M.A., F.R.S.
1929–1931. C. E. STROMEYER, O.B.E., M.Inst.C.E.
1931–1933. B. MOUAT JONES, D.S.O., M.A.
1933–1935. JOHN ALLAN, F.C.S.
1935–1937. R. W. JAMES, M.A., B.Sc.
1937–1939. R. H. CLAYTON, M.Sc.
1939–1940. D. R. HARTREE, M.A., Ph.D., M.Sc., F.R.S.
1940–1944. H. J. FLEURE, M.A., D.Sc., F.R.S.
1944– M. POLANYI, PH.D., M.Sc., M.D.

LIST OF HONORARY MEMBERS OF THE SOCIETY.

Date of Election.

Apr. 26th, 1892. C. LIEBERMANN.
Apr. 17th, 1894. A. GOUY.
do. SIDNEY VINES.

* Died May 16th, 1925.

Date of Election.	
Apr. 17th, 1894.	EMIL WARBURG.
Apr. 30th, 1895.	SIR JOSEPH JOHN THOMSON, O.M.
Apr. 24th, 1900.	SIR J. ALFRED EWING.
do.	ANDREW RUSSELL FORSYTH.
do.	ROBERT RIDGEWAY.
May 13th, 1902.	SIR JOSEPH LARMOR.
do.	SIR OLIVER LODGE.
Apr. 28th, 1903.	FRANK WIGGLESWORTH CLARKE.
Apr. 5th, 1910.	WALTHER NERNST.
Nov. 28th, 1922.	NIELS BOHR.
Apr. 13th, 1926.	SAMUEL ALEXANDER, O.M.
do.	ARNOLD SOMMERFELD.
Nov. 16th, 1926.	SIDNEY J. HICKSON.
do.	SIR HENRY A. MIERS.
May 13th, 1930.	F. E. WEISS.

LIST OF CORRESPONDING MEMBERS OF THE SOCIETY.

Date of Election.	
Feb. 3rd, 1920.	W. S. MURPHEY.
Nov. 1st, 1921.	MRS. C. W. PALMER.
Nov. 29th, 1923.	H. F. COWARD.
Apr. 1st, 1924.	G. F. FOWLER.
Dec. 16th, 1924.	G. SENN.
Oct. 13th, 1925.	H. G. A. HICKLING.
Nov. 11th, 1941.	MISS E. OWEN.
Dec. 12th, 1944.	H. J. FLEURE.

THE COUNCIL
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FOUNDED 1781.

Elected May 23rd, 1944.

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THE COUNCIL
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J. D. CHORLTON, M.Sc.
H. HAYHURST, F.I.C., A.M.I.Chem.E.
P. GUTHLAC JONES.
J. KENNER, D.Sc., Ph.D., F.R.S.
W. A. SILVESTER, M.Sc.
NORMAN SMITH, D.Sc., F.C.S.

Assistant Secretary and Librarian.

W. COVENTRY.

LIST OF SOCIETIES AND INSTITUTIONS

TO WHICH THE *Memoirs and Proceedings* ARE SENT.

Societies and Institutions present their publications to the Society's Library with the exception of those marked with a dagger (†).

Aberystwyth. †National Library of Wales.

Abo. Akademie Bibliotek.

Adelaide. Royal Society of South Australia. South Australian Museum. Public Library Museum and Art Gallery of South Australia.

Amsterdam. Koninkliijke Akademie van Wetenschappen. Société Mathématique. Bibliothek van het Wickundig en Genootschap.

Auckland. The Auckland Institute and Museum.

Augsburg. Der naturwissenschaftliche Verein für Schwaben.

Baltimore. Johns Hopkins University.

Bamberg. Naturforschende Gesellschaft.

Bangalore (Madras). Indian Institute of Science.

Basle. Naturforschende Gesellschaft. Naturforsch. Gesellsch. Universitats.-Bibliothek. Helvetica Chimica Acta.

Batavia. Natuurkundige Vereeniging in Nederlandsch-Indië. Bataviaasch Genootschap van Kunsten en Wetenschappen.

Bath. Bath and West and South Counties Society.

Belgrade. Académie Royale Serbe.

Belfast. Naturalists' Field Club.

Bergen. Geofysick Institute.

Berkeley. University of California.

Berlin. Deutsche chemische Gesellschaft. Preussische Geologische Landesanstalt. Preussische Akademie der Wissenschaften. Gesellschaft der Naturforschender Freunde.

Besançon. Société d'émulation de Doubs.

Birmingham. Natural History and Philosophical Society.

Bloemfontein. National Museum.
Bologna. Reale Accademia delle Scienze dell'Istituto.
Bombay. Branch of the Royal Asiatic Society of Bengal.
Bonn. Naturhistorischer Verein der preussischen Rheinlande und Westfalens.
Bordeaux. Société des Sciences physiques et naturelles.
Boston. American Academy of Arts and Sciences.
Boulder. University of Colorado.
Bremen. Naturwissenschaftlicher Verein.
Brisbane. Royal Geographical Society of Australasia. Queensland Museum. Royal Society of Queensland.
Bristol. Naturalists' Society.
Brno. Faculty of Science, Masaryk University.
Brooklyn (N.Y.). Institute of Arts and Sciences.
Brussels. Académie Royale de Belgique. Musée Royal d'Histoire Naturelle de Belgique. Société Belge de Géologie Paléontologie et Hydrologie.
Buckhurst Hill. Essex Field Club.
Buenos Aires. Sociedad Cientifica Argentina.
Buffalo. Society of Natural Sciences.

Caen. Académie nationale des Sciences, Arts et Belles-Lettres. †Société Linnéenne de Normandie.
Calcutta. Agricultural Research Institute (Pusa). Geological Survey of India. Indian Association for the Cultivation of Science. Meterological Department of India (Poona). Royal Asiatic Society of Bengal.
Cambridge. Philosophical Society. †University Library.
Cambridge (Mass.) Harvard College. †Massachusetts Institute of Technology Library.
Canberra. National Library.
Cape Town. Royal Society of South Africa. South African Museum.
Cardiff. Naturalists' Society.
Catania. Accademia Gioenia di Scienze naturali.
Chambéry. Académie des Sciences. Belles-Lettres et Arts de Savoie.
Changsa. Geological Survey of China.
Chapel Hill. Elisha Mitchell Scientific Society.

Charlottenburg. Physikalischer-Technischer Reichsanstalt.

Cherbourg. Société nationale des Sciences naturelles.

Chicago. Astrophysical Journal. Field Museum of Natural History. University of Chicago Library.

Cincinnati. Lloyd Library and Museum. †American Association for the Advancement of Science. Society of Natural History.

Clermont-Ferrand. La Société des amis de l'Université de Clermont.

Colorado Springs. Colorado College Coburn Library.

Columbia. University of Missouri.

Columbus. Ohio Journal of Science. Ohio State University.

Copenhagen. Kongeligt Danske Videnskabernes Selskab. Kongeligt Nordisk Oldskrift-Selskab. Naturhistorisk Förening.

Cracow. Société Polonaise Mathématique.

Cullercoats. See Newcastle-upon-Tyne.

Danzig. Naturforschende Gesellschaft. Westpreussischer Botanisch-Zoologischer Verein.

Davenport. Academy of Natural Sciences.

Delft. Technische Hoogeschool.

Dijon. Académie des Sciences, Arts et Belles-Lettres.

Dorpat. Naturforschende Gesellschaft. Universitas Tartuensis.

Douai. Société d'Agriculture, Sciences et Arts du Département du Nord.

Draguignan. Société d'études scientifiques et archéologiques.

Dublin. †National Library of Ireland. Royal Dublin Society. Royal Irish Academy. †Trinity College Library.

Dunkerque. Société Dunkerquoise pour l'encouragement des Sciences.

Durban. †Corporation Museum.

Edinburgh. Botanical Society. Geological Society. Mathematical Society. †National Library of Scotland. Royal Botanic Gardens. Royal Observatory. Royal Physical Society. Royal Society. Royal Scottish Society of Arts. †Scottish Meteorological Society. University Library.

Elberfeld Naturwissenschaftlicher Verein
Epinal Société d'émulation des départements des Vosges
Erlangen Physikalisch-medizinische Societät
Evreux Société libre d'Agriculture, Sciences, Arts et Belles-Lettres de d'Eure

Falmouth Royal Cornwall Polytechnic Society
Florence (Firenze) Biblioteca Nazionale Centrale
Frankfurt-am-Main Physikalischer Verein Senckenbergische Naturforschende Gesellschaft
Freiburg i Br Naturforschende Gesellschaft

Geneva Institut national Genevois Société de Physique et d'Histoire Naturelle See also Basle
Genova Museo Civico di Storia Naturale
Giessen Oberhessische Gesellschaft fur Natur-und Heilkunde
Glasgow Geological Society Glasgow and Andersonian Natural History and Microscopical Society Royal Philosophical Society †University Library
Gorlitz Naturforschende Gesellschaft
Goteborg Goteborgs Stadtsbibliotek (Hogskole)
Gottingen Gesellschaft der Wissenschaften
Grahamstown Albany Museum
Granville Denison University
Graz Verein des Aertze in Steiermark
Greenwich Royal Observatory

Haarlem Hollandsche Maatschappig der Wetenschappen Musee Teyler Nederlandsche Maatschappig ter bevordering van Nijverheid Geologisch Bureau van het Nederlandsch Mijngebied
Halifax, N S Nova Scotian Institute of Science
Halle Akademie der Naturforscher Naturforschende Gesellschaft und naturwissenschaftlicher Verein
Hamburg Naturwissenschaftlicher Verein Mathematische Gesellschaft
Hanley See Stoke-on-Trent
Hanover Naturhistorische Gesellschaft
Hartford (Conn) Connecticut State Library (Geological and Natural History Survey).

Heidelberg. Badische Sternwarte. Naturhistorischmedizinischer Verein.

Helsingfors. Finska Vetenskaps Societeten. Societas pro Fauna et Flora Fennica.

Hermannstadt. Siebenbürgischer Verein für Naturwissenschaften.

Hobart. Royal Society of Tasmania.

Hong Kong. Royal Observatory.

Hull. †Scientific and Field Naturalists' Club. †Yorkshire Naturalists' Union.

Indianapolis. Department of Geology and Natural Resources of Indiana.

Iowa City. Iowa State University. Iowa Geological Survey.

Ithaca. Cornell University. Agricultural Experimental Station.

Johannesburg. South African Association for the Advancement of Science.

Kazan. Imperial University. Society of Archæology.

Kiel. Naturwissenschaftlicher Verein für Schleswig-Holstein. Institut für Meereskunde der Universität Kiel.

Kiev. Academy of Sciences of the Ukrainian Soviet Socialistic Republic. The Academy Institute for Physical Chemistry.

Kodaikanal. See Madras.

Königsberg i. Pr. Universitäts-Sternwarte. Physikalisch-ökonomische Gesellschaft.

Kyoto. College of Science and Engineering, Imperial University.

Lausanne. Société Vaudoise des Sciences Naturelles.

Lawrence. Kansas University.

Leeds. Geological Association. Philosophical and Literary Society. Yorkshire Geological Society.

Leeuwarden. Friesch Genootschap, van Geschied-, Oudheid -en Taalkunde.

Leicester. Literary and Philosophical Society.

Leiden. Maatschappig der Nederlandsch Letterkunde. Rijks Geologisch—Mineralogisch Museum. Rijks Herbarium. Société Néerlandaises de Zoologie.

Leipzig. Naturforschende Gesellschaft. Jablonowskische Gesellschaft. Sächsische Gesellschaft der Wissenschaften.

Le Mans. Société d'Agriculture, Sciences et Arts de la Sarthe.

Lemberg. Bibliothek der Sevcenk Gesellschaft.

Leningrad. Academy of Sciences of the Union of Socialist Soviet Republics.

Liége. Société Géologique de Belgique. Société Royale des Sciences.

Lille. Société des Sciences d'Agriculture et des Arts. L'Universitaire.

Lima, Peru. Cuerpo de Inginieros de Minas del Peru.

Lincoln, U.S.A. Nebraska Geological Survey. University of Nebraska.

Lisbon. Observatorio Central Meteorologico. Observacões meteorologicas da Madeira.

Liverpool. Biological Society. Engineering Society. Geological Society. Hartley Botanical Laboratories. Literary and Philosophical Society.

London. British Association. British Museum (Natural History). British Museum (Library of Pure and Applied Science). British Museum Copyright Office. Chemical Society. Faraday Society. Geological Society. Institution of Civil Engineers. Institution of Electrical Engineers. Institution of Mechanical Engineers. Linnean Society. Mathematical Society. Meteorological Office. National Central Library. Patent Office. Physical Society. Quekett Microscopical Society. Royal Society. Royal Astronomical Society. Royal Geographical Society. Royal Horticultural Society. Royal Institute of British Architects. Royal Institution of Great Britain. Royal Meteorological Society. Royal Observatory. Royal Society of Arts. †Subject Index to Periodicals. University Library. Zoological Society.

Lucca. Reale Accademia Lucchese di Scienze, Lettere, ed Arti.

Lund. The University Library.

Luxembourg. Institut Grand Ducal de Luxembourg.

Lwow. See Lemberg.

Lyon. Académie des Sciences. L'Université.

Madison. Wisconsin Academy of Sciences, Arts and Letters, Wisconsin Geological and Natural History Survey.

Madras. Observatory (Kodaikanal). University.

Madrid. Academia de Ciencias. Sociedad Matemática Española.

Manchester. Association of Engineers. †Chetham's Library. †Christie Library. Conchological Society. Geographical Society. Geological Association. Microscopical Society. †Municipal College of Technology. †Central Library. Shirley Institute. Statistical Society. Textile Institute.

Manhattan. Library of Kansas State College of Agriculture and Applied Science.

Manila. Bureau of Science. Ethnological Survey.

Marburg. Gesellschaft zur Beförderung der gesammten Naturwissenschaften.

Marseilles. Faculté des Sciences de l'Université.

Melbourne. Royal Society of Victoria.

Metz. Académie de Metz.

Mexico. Instituto Geológico. Academia Nacional de Ciencias. "Antonio Alzate."

Middleburg. Zeeuwsch Genootschap der Wetenschappen.

Milan. Reale Istituto Lombardo di Scienze e Lettere. Reale Osservatorio di Brera in Milano (Merati, Como.). Società Italiana di Scienze Naturali, e Museo Civico.

Minneapolis. University of Minnesota. †Academy of Natural Sciences.

Missoula. University of Montana.

Modena. Regia Accademia di Scienze, Lettere ed Arti.

Montevideo. Museo de Historia Natural.

Montpellier. Académie des Sciences et Lettres.

Moscow. Société des Naturalistes de Moscou.

Munich. Bayerische Akademie der Wissenschaften.

Nancy. Société des Sciences de Nancy.

Naples. Accademia delle Scienze fisiche e matematiche. Accademia di Archeologia, Lettere e Belle Arti. Società Reale di Scienze.

Neuchâtel. Société neuchâteloise des Sciences naturelles.

Newcastle-upon-Tyne Dove Marine Laboratories, Cullercoats. †Literary and Philosophical Society. Natural History Society of Northumberland, Durham, and Newcastle-upon-Tyne. University of Durham Philosophical Society.

New Haven (Conn.). Connecticut Academy of Arts and Sciences. Bingham Oceanographic Collection.

New York. Academy of Sciences. American Chemical Society. American Mathematical Society. American Museum of Natural History. Meteorological Observatory (Central Park). The Vanderbilt Marine Museum.

Nimes. Académie de Nîmes.

Norman. Oklahoma Academy of Science.

Norwich. Norfolk and Norwich Naturalists' Society.

Offenbach. Der Offenbacher Verein für Naturkunde.

Oporto. Academica Polytechnica Porto.

Oslo. Norske Videnskaps Akademie. Norsk Meteorologisk Institut. Observatorium. Bibliothèque de l'Université Royale de Norvège.

Ottawa. Dominion Astrophysical Observatory. Geological Survey of Canada. Royal Society of Canada.

Oxford. †Bodleian Library. Radcliffe Library.

Palermo. Reale Accademia di Scienze, Lettere, e Belle Arti.

Paris. Académie des Sciences. École nationale supérieure des Mines. École polytechnique. Muséum d'Histoire naturelle.

Peiping. Geological Society of China.

Philadelphia. Academy of Natural Sciences. American Philosophical Society. Franklin Institute. †Philadelphia Commercial Museum. Wagner Free Institute of Science.

Pietermaritzburg. †Government Geologist, Surveyor General's Office. Natal Government Museum.

La Plata. Direccion General de Estadistica de la Prov. Buenos Aires. Universidad Nacional, Facultad de Ciencias Fisico-Matematicas.

Plymouth. Plymouth Institution and Devon and Cornwall Natural History Society.

Poona. (See Calcutta.)

Portici. Laboratorio di Zoologia generale e agraria, R. Scuola sup. di Agricoltura.

Prague. Böhmische Gesellschaft der Wissenschaft.

Pretoria. The University.

Puget Sound. See Seattle.

Pusa. See Calcutta.

Rennes. Société Scientifique de Bretagne.

Rheims. Académie nationale.

Riga. Naturforscher Verein.

La Rochelle. Société des Sciences naturelles de la Charente inférieure.

Rochdale. Literary and Scientific Society.

Rochester, N.Y. Academy of Science.

Rock Island. Augustana College Library.

Rome. Institut International d'Agriculture. Reale Accademia dei Lincei. Società Italiana per il progresso delle Scienze. Vatican Observatory (Specola Vaticana).

Rostock. Verein der Freunde der Naturgeschichte in Mecklenburg.

Rouen. Académie des Sciences.

Sacramento. See Berkeley.

St. Louis. Missouri Botanical Garden. †Academy of Science. The Washington University.

St. Paul. See Minneapolis.

Salford. †Royal Museum and Library.

San Diego. Society of Natural History.

San Francisco. California Academy of Sciences.

Santiago. Deutscher wissenschaftlicher Verein.

Sassari. Regia Università Istituto Fisiologico.

Seattle. University of Washington. Oceanographical Laboratories. Puget Sound Marine Biological Station.

Sendai. Tohoku Imperial University.

Sheffield. Midland Institute of Mining, Civil and Mechanical Engineers. Safety in Mines Research Board Laboratories.

Shrewsbury. Caradoc and Severn Valley Field Club.

Simla. See Calcutta.

Southport. Fernley Observatory.

Stockholm. Entomologiska Föreningen. Kongeliga Svenska Vetenskaps-Akademi. Royal Library. Sveriges Geologiska Undersökning. Stockholms Högkolas Bibliotek.

Stoke-upon-Trent. North Staffordshire Field Club.

Stratford. The Essex Field Club.

Swansea. Scientific and Field Naturalists' Society.

Sydney. Australian Museum. Linnean Society of New South Wales. Royal Society of New South Wales.

Tashkent. L'Université de l'Asie Centrale.

Taihoku. Imperial University.

Tartu. See Dorpat.

Teddington. National Physical Laboratory

Tiflis. Geophysikalisches Observatorium Georgiens.

Tokyo. Faculty of Science, Imperial University of Tokyo. Imperial Academy. Institute of Electrical Engineers of Japan. Institute of Physical and Chemical Research Physico-Mathematical Society of Japan. National Research Council of Japan.

Toronto. University Library.

Toulouse. Académie des Sciences, Inscriptions, et Belles-Lettres.

Trondhjem. Kongelige Norske Videnskabers Selskab Museet.

Troyes. Société Académique d'Agriculture de l'Aube.

Tufts, Massachusetts. Tufts College.

Uccle. L'Observatoire royale et l'Institut royal Météorologique de Belgique.

Ukraine. (See Kiev.)

Upsala. Kongeliga Universitet. Kongeliga Vetenskaps-Societeten.

Urbana. Illinois State Geological Survey. Illinois State Laboratory of Natural History. University of Illinois.

Utrecht. Koninklijk Nederlandsch Meteorologisch Instituut. Provincial Utrechtsch Genootschap van Kunsten en Wetenschappen.

Venice. Reale Istituto Veneto di Scienze, Lettere, ed Arti.
Victoria, B.C. Dominion Astrophysical Observatory.
Vienna. Akademie der Wissenschaften. Universitäts-Sternwarte. Naturhistorisches Museum. Zoologisch-Botanische Gesellschaft. Oesterreichische Gesellschaft für Meteorologie.

Washington University. See St. Louis, Mo.
Washington, University of. See Seattle.
Washington, D.C. Bureau of Standards, Dept. of Commerce and Labor. Carnegie Institute. Smithsonian Institution, Bureau of Ethnology. Smithsonian Institution, United States National Museum. U.S. Coast and Geodetic Survey. U.S. Department of Agriculture. U.S. Geological Survey. U.S. Naval Observatory. †U.S. Patent Office.
Watford. Hertfordshire Natural History Society and Field Club.
Wellington, N.Z. Royal Society of New Zealand.
Wiesbaden. Nassauischer Verein für Naturkunde.
Wurzburg. Physikalisch-medizinische Gesellschaft.

York. Yorkshire Philosophical Society.

Zürich. Naturforschende Gesellschaft. Schweizerischer Meteorologische Central-Anstalt.

LIST OF ORDINARY MEMBERS OF THE SOCIETY, MAY, 1943.

* *Members who have died during the last two Sessions.*

Year of Election.

1928. Eric Ahlquist, The Croft, Ladybrook Road, Bramhall Park, Cheadle Hulme, Cheshire.

1920. Miss A. C. Alexander, B.Sc., c/o Messrs. Tootal Broadhurst Lee Co. Ltd., 56, Oxford Street, Manchester, 1.

1920. John Allan, F.C.S., 18, Moorfield Road, West Didsbury, Manchester, 20.

1922. J. T. Allpass, 34, Roxton Road, Heaton Chapel, Stockport.

1942. Dr. Alexander Altmann, 38, Waterpark Road, Salford, 7.

1921. W. Anderson, B.Sc., The College of Technology, Manchester, 1.

1928. G. E. Archer, M.B., Ch.B., D.L.O., F.R.C.S.(Ed.), West Thorpe, Park Road, Bowdon, Cheshire.

1943. A. Leslie Armstrong, M.C., M.Sc., F.S.I., F.S.A., 20, Princess Street, Manchester.

1926. J. R. Ashworth, D.Sc., 55, King Street South, Rochdale.

1920. F. W. Bailey, Haven House, Broadbottom, Cheshire.

1940. Mrs. E. A. Bardsley, Alexandra House, 7, Queens Road, Oldham.

1938. F. H. Bentley, M.B., F.R.C.S., 1, Lorne Street, Upper Brook Street, Manchester, 13.

1919. W. H. Bentley, D.Sc., F.C.S., Logan Rock, 188, Birkenhead Road, Meols, Wirral, Cheshire.

1937. Professor P. M. S. Blackett, M.A., F.R.S., St. Clare, Park Avenue, Ruislip, Middlesex.

1920. R. W. Blakeley (Life Member), 299, Great Clowes Street, Salford, 7.

1914. Frank Bowman, M.A., M.Sc.Tech., 12, Clifton Avenue, Fallowfield, Manchester, 14.

1914. Major A. W. Boyd, M.C., M.A., F.R.E.S., Frandley House, Near Northwich.

Year of Election.

1927. J. Crighton Bramwell, M.A., M.D., F.R.C.P., 15, Lorne Street, Manchester, 13.
1936. W. H. Brindley, M.C., M.A., M.Sc., Ph.D., 11, Pikes Lane, Glossop, Derbyshire.
1938. F. J. Brown, M.Sc., The University, Manchester, 13.
1934. Ernest Brunner, Ph.D., Oak Tree Cottage, Castle Hill, Prestbury.
1929. H. E. Buckley, D.Sc., Bradda, Hazelhurst Road, Worsley, Lancs.
1936. *Professor W. Ll. Bullock, M.A., Ph.D., Arborfield, Langham Road, Bowdon, Cheshire.
1925. G. N. Burkhardt, M.Sc., Ph.D., F.I.C., The University, Manchester, 13.
1941. Miss A. Burton, Slethos House, 68, Sackville Street, Manchester, 1.
1920. Miss Marion Chadwick, M.Sc.Tech., 1, Didsbury Road, Stockport.
1899. D. L. Chapman, M.A., F.R.S., Jesus College, Oxford.
1943. Professor H B. Charlton, M.A , The University, Manchester, 13.
1943. Socrates Emanuel Chiotides, 29, Minshull Street, Manchester, 1.
1929. J. D. Chorlton, M.Sc., 62, Palatine Road, Withington, Manchester, 20.
1939. G. F. Clayton, 1, Parkfield Road, Didsbury, Manchester.
1929. J. H. Clayton, Lymm Hall, Lymm, Cheshire.
1920. R. H. Clayton, M.Sc., 1, Parkfield Road, Didsbury, Manchester, 20.
1922. Miss Gladys Clegg, M.Sc., 28, Winwood Road, East Didsbury, Manchester, 20.
1941. John Coatman, C.I.E., M.A., c/o The Firs, Fallowfield, Manchester, 14.
1928. A. F. Core, M.Sc., The University, Manchester, 13.
1928. C. G. Core, M.Sc., The University, Manchester, 13.
1938. T. G. Cowling, M.A., D.Phil., The University, Manchester, 13.

Year of Election.

1934. Miss R. E. S. Cox, Kingsmoor School, Glossop, Derbyshire.

1916. Mrs. M. B. Craven, M.Sc.Tech. (Life Member), College of Technology, Manchester, 1.

1944. H. S. Critchley, Three Gates, Higher Disley, Cheshire.

1919. Miss Mary Cunningham, D.Sc., 27, Clarence Terrace, Bollington, Nr. Macclesfield.

1923. George W. Cussons, The Technical Works, Lower Broughton, Manchester, 7.

1929. J. A. Darbyshire, M.Sc., Melandra, Kershaw Street, Failsworth, Manchester.

1944. William Dick, M.A., K.C., 105, Station Road, Cheadle Hulme, Cheshire.

1942. Miss Lois Dickinson, 31, Charnock Avenue, Wollaton Park, Nottingham.

1918. Miss Annie Dixon, M.Sc., F.R.M.S., (Life Member), Kauguri, Batchwood Drive, St. Albans.

1930. Professor J. M. F. Drummond, M.A., F.R.S.E., 87, Wellington Road, Fallowfield, Manchester, 14.

1941. Morris Feinmann, 18, Roston Road, Salford, 7.

1942. W. R. Fielding, M.A., M.Sc., M.Ed., Manor House, Manor Road, Fleetwood.

1924. A. P. M. Fleming, C.B.E., M.Sc.Tech., M.I.M.E., Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.

1932. Professor H. J. Fleure, M.A., D.Sc., F.R.S., Bowdoin College, Brunswick, Maine, U.S.A.

1940. R. P. Foulds, M.Sc., F.I.C., F.T.I., c/o Messrs. Tootal Broadhurst Lee Co. Ltd., 56, Oxford Street, Manchester, 1.

1922. P. Gaunt, A.I.C., Pentire, Park Lane, Hale, Cheshire.

1922. A. Gill, B.Sc., A.I.C., Hardwick, 30, Woodhill Drive, Prestwich, Nr. Manchester.

1926. W. Howard Goulty (Life Member), 6, Brown Street, Manchester, 1.

Year of Election.

1944. Julius Grant, M.Sc., Ph.D. (Lond.), F.R.I.C., Standleigh, Ringley Road, Whitefield, Manchester.

1929. Professor D. R. Hartree, M.A., Ph.D., F.R.S. (Life Member), 1, Didsbury Park, Didsbury, Manchester, 20.

1924. H. Hayhurst, F.I.C., A.M.I.Chem.E., Fouray, Parkfield Road, Didsbury, Manchester, 20.

1924. Mrs. H. Hayhurst, M.Sc., Fouray, Parkfield Road, Didsbury, Manchester, 20.

1921. D. C. Henry, M.A., The University, Manchester, 13.

1919. D. M. Henshaw, c/o Messrs. W. C. Holmes & Co. Ltd., Engineers, Huddersfield.

1928. J. B. M. Herbert, M.Sc., The University, Manchester, 13.

1942. Professor D. H. Hey, King's College, Strand, London, W.C.2.

1943. Allan Howard Hilton, 135, Great Clowes Street, Manchester, 7.

1944. Samuel Hird, O.B.E., M.Sc., 12, Oakland Avenue, Stockport.

1936. K. G. Holden, B.A., Downshot, Alderley Edge, Cheshire.

1936. N. N. Holden, Braeside, Altrincham, Cheshire.

1943. Ernest Hollings, Dunleath, 17, Alexandra Road, Sale, Cheshire.

1944. Rev. R. V. Holt, Unitarian College, Victoria Park, Manchester, 14.

1920. T. Horner, M.Sc.Tech., A.I.C., (Life Member), c/o The District Bank, Dalaunay Road, Crumpsall, Manchester, 8.

1926. O. R. Howell, B.Sc., Ph.D., Spey Lodge, 29, Palatine Road, Withington, Manchester, 20.

1909. Frederick Howles, D.Sc., Glenluce, Waterpark Road, Broughton Park, Manchester, 7.

1944. Frank Howlett, M.Sc., Ph.D., 49, Parrswood Avenue, Didsbury, Manchester, 20.

1919. Henry Humphreys, 101, Frederick Street, Oldham.

Year of Election.

1923. J. Wilfrid Jackson, D.Sc., F.G.S., The Manchester Museum, The University, Manchester, 13.

1943. Professor Willis Jackson, Penlee, Knutsford Road, Wilmslow.

1923. R. W. James, B.Sc., The University, Cape Town, South Africa.

1943. Professor Geoffrey Jefferson, High Bank, Stenner Lane, Didsbury, Manchester, 20.

1943. Mrs. Jefferson, High Bank, Stenner Lane, Didsbury, Manchester, 20.

1942. C. W. Jones, M.A., Ellesmere House, Ellesmere Park, Eccles, Manchester.

1924. Francis Jones, F.R.I.B.A., 178, Oxford Road, Manchester, 12.

1923. P. Guthlac Jones, Malista, Limefield Road, Kersal, Manchester, 7.

1928. Professor J. Kenner, D.Sc., Ph.D , F.R.S., The College of Technology, Manchester, 1.

1940. C. M. Keyworth, M.Sc. (Leeds), F.I.C., A.M.I.Chem E., Churnet Works, Leek, Staffs.

1940. P. Krug, Dr. Nat. Science (Prague), Manchester Oxide Co. Ltd., Canal Street, Collyhurst, Manchester, 10.

1931. H. S. Land, 24, Hillington Road, Ashton-on-Mersey, Cheshire.

1909. Professor W. H. Lang, M.B., C.M., D.Sc., M.Sc., F.R.S., 2, Heaton Road, Withington, Manchester, 20.

1919. J. E. Lea, B.Sc., M.I.Mech.E., c/o Lea Recorder Co. Ltd., Recorder House, Cornbrook Park Road, Manchester, 15.

1917. Sir Kenneth Lee, LL.D., Messrs. Tootal Broadhurst Lee Co., Ltd., 56, Oxford Street, Manchester, 1.

1940. H. R. Leech, The Lindens, Balmoral Road, Grappenhall, near Warrington.

1931. Miss C. M. Legge, M.A., A.R.C.A., 115, Banbury Road, Oxford.

1943. Miss Myee Dorothy Leigh, M.A., Lyncroft, Higher Ainsworth Road, Radcliffe, Manchester.

Year of Election.

1943. Miss Margaret Lever, Lyncroft, Higher Ainsworth Road, Radcliffe, Manchester.

1944. Miss E. M. Lind, B.Sc., Ph.D., Ashburne Hall, Fallowfield, Manchester, 14.

1941. W. A. Locan, The Firs, Talbot Road, Glossop.

1938. A. C. B. Lovell, B.Sc., Ph.D., 29, Parkwood Road, Northenden.

1928. H. Lowery, D.Sc., Ph.D., M.Ed., F.Inst.P., F.C.P., Principal, South-West Essex Technical College, Forest Road, London, E.17.

1936. G. W. Mack, B.A., 30, Lonsdale Road, Manor Road, Levenshulme, Manchester, 19.

1941. Rev. H. McLachlan, M.A., D.D, 11, Sydenham Avenue, Liverpool, 17.

1943. Miss Marion V. Malcolm-Hayes, Mayfield, The Hough, Wilmslow.

1930. Miss I. Manton, B.A., Sc.D., Ph.D, The University, Manchester, 13.

1931. E. N. Marchant, Whetherstones, Wilbraham Road, Chorlton-cum-Hardy, Manchester, 21.

1941. A. R. Martin, 20, Styal Road, Wilmslow, Cheshire.

1929. H. G. Mather, Sunnymead, Hamilton Road, Whitefield.

1944. J. M. Meek, 79, Temple Road, Sale, Cheshire.

1939. Mrs. A. D. Melland, 17, Ladybarn Road, Fallowfield, Manchester, 14.

1939. C. H. Melland, M.D., 17, Ladybarn Road, Fallowfield, Manchester, 14.

1927. W. Melland, M.A., J.P., 1B, Cooper Street, Manchester, 2.

1944. Rev. F. H. A. Micklewright, M.A., 25, Albert Road, Whalley Range, Manchester.

1936. Professor John Morley, Ch.M., F.R.C.S., The Elms, Wilmslow Road, Didsbury, Manchester, 20.

1912. J. E. Myers, O.B.E., D.Sc., College of Technology, Manchester, 1.

1942. *Sir Christopher T. Needham, Fair Oak, Palatine Road, West Didsbury, Manchester, 20.

1927. J. M. Nuttall, D.Sc., The University, Manchester, 13.

Year of Election.

1936. T. H. Oliver, M.D., Northern Assurance Buildings, Albert Square, Manchester, 2.

1942. David Pearson, B.A., 22, Dryden Avenue, Cheadle, Cheshire.

1934. Professor M. Polanyi, M.D., Ph.D., M.Sc , F.R.S., 30, Sandileigh Avenue, Withington, Manchester, 20.

1931. Professor W. J. Pugh, O.B.E., B.A., D.Sc., F.G.S., Rathen House, Spath Road, Didsbury, Manchester, 20.

1931. A. McLean Ranft, 1, Framingham Road, Brooklands, Cheshire.

1923. Professor H. S. Raper, C.B.E., D.Sc., M.B., Ch.B., M.Sc., F.R.S., The University, Manchester, 13.

1929. Dr. W. J. Sutherland Reid, Cringle, Cheadle, Cheshire.

1920. Professor A. D. Ritchie, M.A., (Life Member), The University, Manchester, 13.

1909. Miss Rona Robinson, M.Sc., F.I.C., (Life Member), Mosley Villa, Mitford Road, Fallowfield, Manchester.

1943. Gregory G. Sarris, c/o Messrs. R. Street & Co., 15, Cross Street, Manchester.

1944. R. U. Sayce, M.A., M.Sc., The University, Manchester, 13.

1919. F. Scholefield, M.Sc., The College of Technology, Manchester, 1.

1931. J. Shirley, M.Sc., Department of Geology, The University, Sheffield, 10.

1920. W. A. Silvester, M.Sc. (Life Member), 4, Claremont Road, Cheadle Hulme, Cheshire.

1941. A. P. Simon, Lyndale, West Didsbury, Manchester, 20.

1915. Sir Ernest D. Simon, M.A., M.Inst.C.E., Broomcroft, Ford Lane, Didsbury, Manchester, 20.

1906. Norman Smith, D.Sc., F.C.S., 22, Broadway, Withington, Manchester, 20.

1926. W. M. Speight, M.Sc., The Grammar School, Manchester, 13.

Year of Election.

1911. Miss Laura E. Start, M.Ed., Holmwood, Mayfield Road, Kersal, Manchester, 7.

1921. Harold Stevenson, F.I.C., Slievemore, 9, Westwood Road, Heald Green, Cheshire.

1936. Sir John S. B. Stopford, M.D., Sc.D., F.R.S., The University, Manchester, 13.

1936. J. F. Straatman, Ir. (Delft), A.T.I., 208, Heywood Road, Prestwich, Manchester.

1924. Stephen H. Straw, D.Sc., The University, Manchester, 13.

1924. G. A. Sutherland, M.A., Dalton Hall, Victoria Park, Manchester, 14.

1938. H. Frankland Taylor (Life Member), Innisfree, Lynne Road, Disley.

1937. W. H. Taylor, Ph.D., D.Sc., 30, Broadway, Withington, Manchester, 20.

1919. F. H. Terleski, Oakwood, Hilton Lane, Prestwich, Manchester.

1921. Professor F. C. Thompson, B.Sc., M.Sc., D.Met., The University, Manchester, 13.

1922. Franklin Thorp, Birchdene, Whitefield, Nr. Manchester.

1942. H. T. Thorp, "Beechwood," Pinfold Lane, Whitefield.

1938. Professor A. R. Todd, D.Sc., Dr.Phil. nat., D.Phil., Chemical Laboratory, Pembroke Street, Cambridge.

1942. Dr. L. S. Torrance, 2, Emma Street, Waterloo Road, Cheetham Hill, Manchester, 8.

1931. F. C. Toy, D.Sc., Tregays, Fletsand Road, Wilmslow, Cheshire.

1936. Miss H. I. Tuer, 3, Holly Avenue, Cheadle Hulme, Cheshire.

1931. H. A. Turner, M.Sc., A.I.C., (Life Member), Ministry of Supply, Chemical Defence Research Station, Porton, Wilts.

1944. Miss Emily Verity, B.Sc., 19, Wellington Road, Fallowfield, Manchester, 14.

Year of Election.

1921. H. Walkden (Life Member), The Raft, Derbyshire Road, Sale, Cheshire.

1944. R. D. Waller, M.B.E., M.A., Extra-Mural Department, The University, Manchester, 13.

1924. C. Walmsley, M.A., 6, Studley Avenue, Halifax, Nova Scotia.

1936. Professor T. B. L. Webster, M.A., (Life Member), The University, Manchester, 13.

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NOTE

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The Reactions of Organic Halides in Solution.

By Alwyn G. Evans.

Received 1*st December*, 1945.

INTRODUCTION.

There have been two main attempts to develop a theory for the mechanism of organic halide substitution reactions in solution: one due to Hughes and Ingold[1], and the other due to Polanyi and co-workers[2]. Ingold and co-workers have shown that the solvolytic and negative ion reactions of organic halides may occur either by a unimolecular S_N1 mechanism, or by a bimolecular S_N2 mechanism. Polanyi and co-workers have discussed these unimolecular and bimolecular reactions in terms of energy surfaces and have attempted to calculate the activation energies concerned. This method, although involving some assumptions in respect of quantities as yet unknown, indicates those magnitudes which must be determined for the further elucidation of the problem.

Since the general discussion by Ogg and Polanyi[2c] of the reactions of organic halides in solution, much progress has been made in the estimation of the quantities involved in this problem: carbon-halogen bond strengths, ionisation potentials of organic radicals, heats of solution of ions, and steric hindrance. It was thought that another review of this field in terms of the Polanyi theory and making use of this more recent data would be profitable. This has been attempted in the present paper. The theory of Hughes and Ingold[1] and that of Meer and Polanyi[2a] and Ogg and Polanyi[2c] are first briefly described. Then the field is discussed from the point of view of the Polanyi theory making use of the newer material available.

(1) *Review of Experimental Results.*

In Table 1 several series of reactions are given which show how the reactivity of the halide R – X is affected by changes in the nature of R. A series of provisional carbon-iodine bond strengths is also included for comparison.

TABLE I.

Reaction \ R =	RELATIVE RATE.													
	Me	Et	*i*-Pr	*t* Bu	*n*-Pr	*s* Bu	*n* Bu	*n* Am	*i* Am	Neopentyl	Allyl	Benzyl	Vinyl	Phenyl
(1) $RCl+I^-$	—	1	0.0077	0·0092	0.53	—	0.52	0·65	0.35	—	38	94	—	—
(2) $RBr+Br^{*-}$	—	—	0.035	—	0.5	0·036	0.054	—	—	—	—	—	—	—
(3) $RI+I^{*-}$	—	1	0.046	—	0.66	—	—	—	—	—	—	—	—	—
(4) $RI+I^{*-}$	—	1	0.042	—	0.62	0.064	0.47	0.58	0.25	—	—	—	—	—
(5) $RBr+OH^-$	12.5	1	0.028	~0	—	—	—	—	—	—	—	—	—	—
(6) $RBr+H_2O$	0.59	1	26.2	$\sim 10^8$	—	—	—	—	—	—	—	—	—	—
(7) $RBr+H_2O$	2.5	1	1.7	7,250	—	—	—	—	—	—	—	—	—	—
(8) $RBr+OEt^-$.	~12	1	—	—	0.28	0.029	—	—	—	$6.5\ 10^{-6}$	—	—	—	—
(9) $RBr+I^-$	—	—	—	—	—	—	0.52	—	—	0.0011	36.4	—	—	—
(10) $RBr+H_2O$	1.8	1	—	—	0.54	0.075	—	—	—	0.0052	—	—	—	—
(11) $RCl+Na$	0.7	1	2.1	4.7	1.6	2.0	2.1	3.2	3.5	—	50	750	0.6	0.6
(12) Provisional R – I Bond Strengths, in kcal	54	52	46.5	45.0	50·0	—	49.0	—	—	—	39.0	43.7	55.0	54.0

Reaction 1. Alkyl chloride and potassium iodide in acetone at 60° C. The values for allyl and benzyl have been extrapolated from data at lower temperatures (3a)

Reaction 2. Reaction of alkyl bromides with radioactive bromine ions at 50° C in aqueous acetone (3b) (The value for *n* Bu appears to be abnormally low in this series.)

Reaction 3. Reaction of alkyl iodides with radioactive iodine ions at 70° C in absolute alcohol (3c)

Reaction 4. Reaction of alkyl iodides with radioactive iodine ions at 50° C in alcoholic solution (3d) (The value for *t*-Bu has been omitted because of its doubtful character.)

Reaction 5. The bimolecular reaction of alkyl bromides with OH^- ions in 80 % aqueous EtOH at 55° C (4)

Reaction 6. Hydrolysis of alkyl bromides in wet formic acid at 100.2° C (5)

Reaction 7. Solvolysis of alkyl bromides in 80 % aqueous EtOH at 55° C (4)

Reaction 8. Relative rates at 95° C. of the reaction of alkyl bromides with sodium ethoxide in dry ethyl alcohol listed by Hughes. (6)

Reaction 9. Reaction of alkyl bromides with potassium iodide in acetone at 25° C (7)

Reaction 10. Reaction of alkyl bromides with 50 % aqueous ethyl alcohol in initially neutral solution at 95° C (8)

Reaction 11. Gas phase reaction of sodium with alkyl chlorides at about 275° C (9) (10) (11)

Reaction 12. Provisional R – I bond strengths obtained from rates of pyrolysis (12)

There are very few data for the vinyl and phenyl halides, but the substitution of the halogen atom in these compounds is known to be difficult.

The main features of these results are the following The rate of reaction of the halide R – X with sodium in the gas phase (reaction 11) increases with decrease in R – I bond strength with one exception The exception, benzyl chloride, reacts with sodium faster than would be expected from the corresponding R – I bond strength. This behaviour has been discussed previously [12, 11] The rate sequence obtained for the reaction of these organic halides with sodium is mainly determined by the carbon-halogen bond strength

The reaction of iodine ions with alkyl chlorides (reaction 1) shows the velocity sequence Et>*s*-Pr≈*t*-Bu The radioactive ion exchange reactions 3 and 4 show the velocity sequence Et>*s*-Pr The reaction of alkyl bromides with OH^- ions (reaction 5) shows the velocity sequence Me>Et>*s*-Pr>*t* Bu The results for the reaction of alkyl chlorides with sodium in the vapour phase (reaction 11), on the other hand, show the opposite rate sequence Me<Et<*s*-Pr<*t*-Bu

The reaction of alkyl bromides with sodium ethoxide (reaction 8) and with aqueous ethyl alcohol (reaction 10) show the rate sequence Me>Et>*n*-Pr>*i*-Bu>neopentyl The reaction of radioactive iodine ions with alkyl iodides (reaction 4) shows the sequence Et>*n* Pr>*i*-Bu The reaction of radioactive bromine ions with alkyl bromides shows the sequence *n* Pr>*i*-Bu In these rate sequences the change in rate is least marked from Et to *n*-Pr The sequence obtained for the first four members of this series, Me to *i*-Bu, is again opposite to that obtained for the reaction of these chlorides with sodium vapour (reaction 11) Me<Et<*n*-Pr<*i*-Bu The reaction rates of neopentyl bromide with sodium ethoxide and iodine ions (reactions 8 and 9) show it to be a slow reaction The corresponding reaction rate with sodium vapour and the R – I bond strength are not known

The reactions of allyl and benzyl halides with iodine ions show the rate sequence Et<Allyl<Benzyl (reactions 1 and 9). In contrast to the other series mentioned above, this rate sequence is the same as that shown by these chlorides in their reaction with sodium vapour, Et<Allyl<Benzyl (reaction 11).

The replacement reactions of the vinyl and phenyl halides are very slow

(2) *Theory of Hughes and Ingold.**

The reactions of organic halides in solution, in particular those involving substitution at a saturated carbon atom, have been extensively studied by Ingold and co-workers[1]. Two types of substitution reactions have been investigated in detail: (*a*) the reactions between organic halides and the solvent, "solvolytic reactions", and (*b*) the reactions between organic halides and negative ions, "negative ion reactions". These workers conclude that reactions of type (*a*) and type (*b*) may each occur by two possible mechanisms, a unimolecular or a bimolecular mechanism. These mechanisms are described as S_N1 and S_N2 respectively, since they refer to substitution by a nucleophilic reagent. For solvolytic reactions these two mechanisms may be represented as follows for the organic halide R–X in aqueous solution :—

$$\left.\begin{array}{l} R-X \xrightarrow{\text{slow}} R^+_{aq} + X^-_{aq} \\ H_2O + R^+_{aq} \xrightarrow{\text{rapid}} R-OH + H^+_{aq} \end{array}\right\} \quad \ldots \quad S_N1.$$

and

$$H_2O + R-X \longrightarrow R-OH + H^+_{aq} + X^-_{aq}. \quad \ldots \quad S_N2.$$

For negative ion reactions the two mechanisms may be written :

$$\left.\begin{array}{l} R-X \xrightarrow{\text{slow}} R^+_{aq} + X^-_{aq} \\ Y^-_{aq} + R^+_{aq} \xrightarrow{\text{rapid}} R-Y \end{array}\right\} \quad \ldots \quad S_N1.$$

and

$$Y^-_{aq} + R-X \longrightarrow Y-R + X^-_{aq} \quad \ldots \quad S_N2.$$

In the negative ion reactions the reaction mechanism may be directly determined by varying the concentration of the reactants since both reactants are present in small concentration. The solvolytic reactions, however, will show first order kinetics irrespective of the actual mechanism involved. For these reactions, therefore, the mechanism must be determined by indirect methods.

Hughes and Ingold consider that the effect of the group R on the reactivity of the halide R–X depends on whether the halide is reacting by the unimolecular mechanism S_N1, or by

* Note added in proof. In a group of papers (*J.C.S.*, 1946, 157, et seq.), which have appeared since this paper was submitted for publication, Dostrovsky, Hughes and Ingold have estimated the effect of steric hindrance in the bimolecular substitution reactions of R–X for the series Me, Et, *s*-Pr, *t*-Bu, and Et, *n*-Pr, *iso*-Bu, neopentyl, and have discussed the part played by steric hindrance in these reactions.

the bimolecular mechanism S_N2 If a change in R involves an increase in the electron accession to the centre of substitution, then this change in R will result in an increase in the unimolecular reaction rate of R – X The result of such an increase in electron accession on the bimolecular reaction rate of R – X, however, is ambiguous It is considered that an increase in electron accession to the reaction centre will tend both to repel the reagent and to expel the replaceable group Because of these opposing tendencies, electron accession to the reaction centre is expected to have a smaller effect on the bimolecular reaction rate than on the unimolecular reaction rate If the electron accession acts as though principally engaged in repelling the reagent the bimolecular rate will be decreased, if the electron accession is mainly engaged in expelling the replaceable group the bimolecular reaction rate will be increased The electron release process $Cl-C-Cl$ in CH_2Cl_2 is assumed to facilitate the unimolecular S_N1 mechanism but to have an inhibitory effect on the bimolecular S_N2 mechanism (ref 6, p 625) On the other hand, the electromeric polarisation $C=C-C-Hal$ in allyl and benzyl halides is assumed to have a very strong facilitating influence on the unimolecular S_N1 mechanism, and a similar, though less powerful, effect on the bimolecular S_N2 mechanism (ref 6, p 628) The high reactivity of the allyl and benzyl halides (Table I, reaction (1)) is attributed by Hughes and Ingold to this electromeric polarisation It is suggested that the alternative polarisation $C=C \leftarrow C-Hal$ could also be effective in facilitating the bimolecular mechanism.

According to Hughes and Ingold, the alkyl groups CH_3, CH_2CH_3, $CH(CH_3)_2$ and $C(CH_3)_3$ are placed in order of increasing ability to release electrons to the centre of substitution The increase in electron release along this series of R will result in a corresponding increase in the reaction rate of the unimolecular S_N1 reaction of R – X, and the rate sequence expected for this type of reaction is Me<Et<*s*-Pr<*t*-Bu

As discussed above, an increase in the electron accession to the reaction centre may be expected to cause an increase or a decrease in the rate of the bimolecular S_N2 reaction. For the series of alkyl groups CH_3 to $C(CH_3)_3$ Hughes and Ingold

assume that in this case the effect of electron accession to the reaction centre is to inhibit the approach of the nucleophilic reagent. Thus, according to Hughes and Ingold, the increase in electron release along this series of R will result in a corresponding decrease in the reaction rate of the bimolecular S_N2 reaction of R – X and the rate sequence expected for this type of reaction is Me>Et>*s*-Pr>*t*-Bu. In this way these authors interpret the rate sequences for the bimolecular reactions (1) and (5) in Table I.

By using a solvent of high ionising capacity and a reactant which is weakly nucleophilic both of which factors will promote the unimolecular mechanism in contrast to the bimolecular mechanism, the rate sequence Me <Et<*s*-Pr<*t*-Bu was obtained for the hydrolysis of alkyl bromides in aqueous formic acid[5], (Table I, reaction (6)). This is the sequence which Hughes and Ingold expect for the unimolecular reaction of R - X

Since, along the series of R, CH_3, CH_2CH_3, $CH(CH_3)_2$, and $C(CH_3)_3$ the increase in electron accession to the reaction centre due to the methyl groups is assumed to increasingly inhibit the bimolecular mechanism and favour the unimolecular mechanism, it is to be expected that a change in the reaction mechanism of R – X from the bimolecular S_N2 to the unimolecular S_N1 may occur along this series. If such a change in mechanism occurs there will be a decrease in reaction rate along this series in the bimolecular region, and an increase in rate in the unimolecular region. This is the way in which Hughes and Ingold interpret the results of the solvolysis of alkyl bromides in 80 % aqueous ethyl alcohol[4]. (Reaction (7), Table I). The rate sequence Me>Et<*s*-Pr<*t*-Bu is found. In this case the solvolysis of the MeBr and EtBr are bimolecular in mechanism; the solvolysis of *t*-BuBr is unimolecular, while that of *s*-Pr is partly bimolecular and partly unimolecular.

The rate of the bimolecular reaction of alkyl bromides with OEt^- ions decreases along the series of R, Me>Et>*n*-Pr>*i*-Bu> Neopentyl[6]. (Table I, reaction (8)). Hughes attributes the decrease along the first four members of this series to the increase in electron accession to the reaction centre as in the Me to *t*-Bu series. In the case of neopentyl bromide he considers that the presence of the third β-methyl group has introduced

an effect which is far larger than that to be expected on the basis of its capacity for the release of electrons, and he concludes that the effect of this last β-methyl group in retarding the bimolecular reaction is steric

The rate sequence found for the solvolytic reactions of these halides[8] is the same as that for their reaction with OEt ions Me>Et>*n*-Pr>*i*-Bu>Neopentyl (Table I, reaction (10)) According to Hughes, the solvolysis of the first four halides of this series is predominantly bimolecular in mechanism, the solvent molecules functioning as nucleophilic reagents, and so the resulting rate sequence is the same as for the bimolecular reaction with OEt^- ions Hughes finds that the solvolysis of neopentyl bromide is unimolecular in mechanism, and thus gives a value for the (usually unobservable) unimolecular rates for primary halides generally

The difficulty of replacing the halogens in vinyl and phenyl halides is attributed by Hughes and Ingold to the electromeric displacement C=C–Hal, which, since it opposes the activation C–Hal, strongly inhibits the unimolecular S_N1 mechanism and also retards the bimolecular S_N2 mechanism, although to a smaller extent (ref 6, p 627)

(3) *Theory of Polanyi and Co-workers*

The mechanism of organic reactions in solution has been discussed by Polanyi and co workers[2] In 1932 Meer and Polanyi[(2a)] compared the reactions of organic halides in solution (reaction 1, Table I) with the corresponding reactions of organic halides with sodium vapour (reaction 11, Table I) The fact that the changes in R ethyl to vinyl and *n*-propyl to allyl had similar effects on both the negative ion reactions and the reactions with sodium vapour was pointed out The fact that along the series of R : primary, secondary, tertiary, although the sodium vapour reactions showed an increase in rate, the negative ion reactions showed a decrease in rate was attributed by Meer and Polanyi to an increase in steric hindrance caused by the number of groups on the α-carbon atom increasing along this series In the reactions with sodium vapour when the attack of the sodium is at the halogen atom (as in the "positive

mechanism "), these groups on the α-carbon atom will have no steric effect on the reaction. In the negative ion reactions, however, when the negative ion attack is at the α-carbon atom, " negative mechanism ", these groups will hinder the reactions sterically. This hindrance will increase along the series from primary to secondary to tertiary.

Ogg and Polanyi[2c] discussed the unimolecular ionisation reactions and the bimolecular negative ion reactions of organic halides in terms of potential energy surfaces, and calculated the activation energies of several negative ion reactions. According to these authors, alterations in the nature of R which weaken the $R-X$ bond will increase the rate of both the unimolecular and the bimolecular reactions unless the change in the nature of R which weakens the $R-X$ bond also causes an increase in the steric hindrance of the bimolecular reaction. The effect of this steric hindrance may out-balance the effect of the weakened bond and cause a decrease in the rate of the bimolecular reaction to accompany an increase in the rate of the corresponding unimolecular reaction. They suggested that the change-over from the bimolecular to the unimolecular mechanism of hydrolysis on passing from primary to tertiary halides (alkaline hydrolysis, Ingold and Hughes, *Nature*, 1933, **132**, 933) is partly due to the fact that increasing the number of groups on the reactive carbon centre produces a weakening of the $R-X$ bond which increases the rate of the unimolecular ionisation and at the same time causes an increase in the steric hindrance of the bimolecular reaction.

PRESENT DISCUSSION.

(1) UNIMOLECULAR REACTIONS.

(1*a*) *General Theory.*

The potential energy curve for the ionisation of the organic halide $R-X$ in aqueous solution has been calculated for the case of CH_3I by Baughan, M. G. Evans and Polanyi[13]. In Figure 1 the potential energy curves calculated by these authors for gaseous CH_3-I, ionic gaseous $CH_3^+ \, I^-$ and solvated $CH_3{}^+{}_{aq}$ $I^-{}_{aq}$ are shown. The solvation heat of the CH_3I molecule has been neglected. On stretching the carbon iodine bond of $R-I$ in aqueous solution the resulting potential energy curve will

initially follow the gaseous R – I curve and finally will follow the solvated ionic curve $R^+_{aq}\,I^-_{aq}$. The shape of the curve in the intermediate region will be determined by the extent of resonance between the two states R – I and $R^+_{aq}\,I^-_{aq}$.

The heat absorbed, Q, in the ionisation

$$R-I_{aq} \rightarrow R^+_{aq} + I^-_{aq}$$

is determined by the following equation :—

$$Q = D + I - E - S^+ - S^-$$

where D is the heat of dissociation of the carbon iodine bond in the gaseous RI molecule.

I is the ionisation potential of the R radical.

E is the electron affinity of the iodine atom.

S^+ is the heat of hydration of the R^+ ion.

S^- is the heat of hydration of the I^- ion.

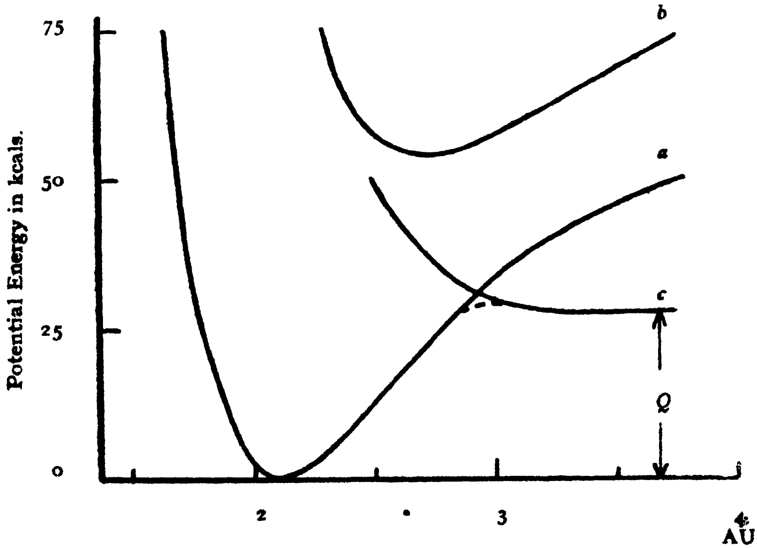


FIGURE 1.

a Potential energy curve for gaseous R – I.

b Potential energy curve for ionic gaseous $R^+\,I^-$.

c Potential energy curve for solvated $R^+_{aq}\,I^-_{aq}$

Q is the endothermicity of the ionisation :

$$RI \rightarrow R^+_{aq} + I^-_{aq}.$$

It was found[13], as shown in Figure 1, that the potential energy curve for the hydrated ions is horizontal from infinite $R^+_{aq}\ I^-_{aq}$ separation up to the point where it crosses the potential energy curve for R – I. This means that the activation energy of the ionisation reaction :—

$$R-I_{aq} \rightarrow R^+_{aq}+I^-_{aq}$$

is practically the same as its endothermicity Q.

This potential energy curve for the ionisation of the organic halide in solution is fundamental for the consideration of the solvolytic and negative ion reactions of organic halides in solution. It is important, therefore, to consider how changes in the nature of the organic radical R will affect the shape of this ionisation curve. For a change in the radical R, the resulting change in the heat of ionisation of the halide R – X is given by the relationship :

$$\Delta Q=\Delta D+\Delta I-\Delta S^+.$$

From this relationship it is seen that a decrease in the homopolar R – X bond strength, and a decrease in the ionisation potential of the radical R will lead to a decrease in the endothermicity of the ionisation reaction. On the other hand a decrease in the heat of solution of the organic positive ion R^+, will lead to an increase in the endothermicity of the ionisation reaction.

As discussed later (Section 1*c*), Baughan, M. G. Evans and Polanyi[13] used a value for the ionisation potential of methyl which was too low. The use of this low ionisation potential will result in the $CH_3{}^+_{aq}\ I^-_{aq}$ repulsion curve *c* lying at a lower energy level than it should do, and thus giving a lower value for the endothermicity of the CH_3I ionisation than is actually the case. The corrected value for this endothermicity is given in Section 1*c*. The relative positions of the curves given in Figure 1, therefore, do not represent the energy diagram for the CH_3I ionisation, but give a general diagram for the ionisation of R – I when R has a low ionisation potential. In Figure 2 the relative positions of the $CH_3{}^+_{aq}\ I^-_{aq}$ repulsion curve and the CH_3 – I extension curve are given using the corrected ionisation potential for the methyl radical.

We will first discuss the changes in Q caused by varying R along the series CH_3, CH_2CH_3, $CH(CH_3)_2$, $C(CH_3)_3$.

(1*b*) *Variation of R – X Bond Strength.*

In this series of R from CH_3 to $C(CH_3)_3$ the R – X bond strength is found to decrease by about 9 kcal; provisional bond strengths for the iodides have been given as: CH_3I 54·0, CH_3CH_2I 52·0, $(CH_3)_2CHI$ 46·5, $(CH_3)_3CI$ 45·0[12]. This decrease in bond strength has been discussed previously and has been related to the increase in resonance energy of the radicals along this series[13]. This decrease in R – X bond strength as R changes from CH_3 to $C(CH_3)_3$ will tend to cause a decrease in the endothermicity Q of the ionisation of R – X in solution.

(1*c*) *Variation of Ionisation Potential.*

Estimates of the ionisation potentials of radicals have been made from electron impact experiments. The most probable value for the ionisation potential of the methyl radical seems to be that of 10·07 e.v. obtained from electron impact experiments on methyl radicals[14]. This value agrees well with those of 10·3 e.v.[15] and 9·9 e.v.[16] obtained from experiments on methane and that of 10·4 e v.[17] from experiments on ethane.

The most probable value for the ionisation potential of the ethyl radical seems to be that of 8·67 e.v. obtained from electron impact experiments on ethyl radicals[14]. This value is in good agreement with that of 8·5 e.v. obtained from experiments on ethane.[18] The value of 9·8 e.v. given for the ionisation potential of the ethyl radical by Delfosse and Bleakney[19] from experiments on *n*-propane was evaluated on the assumption that the carbon-carbon bond strength in *n*-propane is 2·5 e.v. If the more probable value of 3·5 e.v. given by Stevenson[20] for this bond strength were used, the ionisation potential would be evaluated as 8·8 e.v. in good agreement with the values given above for the experiments on ethyl radicals and on ethane.

Thus the change from methyl to ethyl involves a decrease in the ionisation potential of the radical of about 1·4 e.v. or about 32 kcal. This decrease in ionisation potential is much more marked than the corresponding decrease in carbon-halogen bond strength, which is only of the order of 2 kcal[12].

The ionisation potentials of the *s*-propyl and *t*-butyl radicals may be estimated by consideration of the results of those electron

impact experiments in which there can be no doubt as to the particular bond which is broken. This method is adopted in the following discussion.

From the results of electron impact experiments on *n*-propane and *n*-butane the following equations may be written :

$$C_3H_8 \rightarrow C_2H_5^+ + CH_3 + \epsilon - 12{\cdot}21 \text{ e.v.}^{19,21}.$$

$$n-C_4H_{10} \rightarrow n\text{-}C_3H_7^+ + CH_3 + \epsilon - 11{\cdot}21 \text{ e.v.}^{18}.$$

If we take the decrease in carbon-carbon bond strength from $C_2H_5-CH_3$ to $CH_3CH_2CH_2-CH_3$ as 0·13 e.v.[12], the above results indicate a decrease in ionisation potential of about 0·87 e.v. from Et to *n*-Pr. This difference, together with the ionisation potential for ethyl, enables us to estimate the ionisation potential of the *n*-Pr radical as about 7·8 e.v.

From electron impact experiments on iso-butane we may write the equation :

$$i\text{-}C_4H_{10} \rightarrow s\text{-}C_3H_7^+ + CH_3 + \epsilon - 11{\cdot}01 \text{ e.v.}^{18}.$$

If we compare this with the equation given above for n-C_4H_{10}, and take the difference between the carbon-carbon bond strengths involved as 0·17 e.v.[12], we find a value of 7·77 e.v. for the ionisation potential of the *s*-Pr radical.

An estimate of the ionisation potential of a tertiary radical may be obtained by comparing the results of electron impact experiments on *t*-BuCl and *n*-PrCl[21]. From the results of these experiments the following equations may be written :

$$n\text{-PrCl} \rightarrow n\text{-Pr}^+ + \text{Cl} + \epsilon - 11{\cdot}1 \text{ e.v.}$$

$$t\text{-BuCl} \rightarrow t\text{-Bu}^+ + \text{Cl} + \epsilon - 10{\cdot}27 \text{ e.v.}$$

Taking the difference between the carbon-chlorine bond strengths of these two halides as 0·22 e.v.[12] gives a value of 7·19 e.v. for the ionisation potential of the *t*-Bu radical.

If we combine the above equation for *n*-PrCl with the ionisation potential for the *n*-Pr radical, derived earlier, the carbon-chlorine bond strength of *n*-PrCl is found to be 78 kcal. Since the difference between the carbon-halogen bond strengths of methyl and *n*-propyl halides is about 4 kcal.[12], this gives a value of 82 kcal. for the carbon-chlorine bond strength of CH_3Cl. This value agrees closely with that of 83·5 kcal. given by Baughan and Polanyi[22].

The ionisation potentials discussed above give the sequence: Me 10·07 e.v. (232 kcal.), Et 8·67 e.v. (200 kcal.), *n*-Pr 7·80 e.v. (180 kcal.), *s*-Pr 7·77 e.v. (179 kcal.), *t*-Bu 7·19 e.v. (165 kcal.). It thus appears that there is a marked decrease in ionisation potential from Me to *t*-Bu. This decrease which is of the order of 2·9 e.v. or 67 kcal. is much more marked than the corresponding decrease in the carbon-halogen bond strength which is of the order of 9 kcal[12]. Thus the decrease in the ionisation potential along the series Me, Et, *s*-Pr, *t*-Bu will be much more effective than the decrease in the R – X bond strength along this series in tending to cause a decrease in the endothermicity of the ionisation of R – X in solution

In constructing the potential energy curve for the ionisation of CH_3I in aqueous solution, Baughan, M. G. Evans and Polanyi[13] used the value of 7·8 e v. for the ionisation potential of the CH_3 radical. This value was obtained by a method of bracketing The upper limit for the ionisation potential was determined by comparing the energy changes of the process: $CH_3I_{aq} \rightarrow CH_3I_{vap} \rightarrow CH_3 + I \rightarrow CH_3^+ + I^- \rightarrow CH_3{}^+{}_{aq} + I^-{}_{aq}$ (in which the ionisation potential of CH_3 is the only unknown) with the endothermicity of the ionisation: $CH_3I_{aq} \rightarrow CH_3{}^+{}_{aq} + I^-{}_{aq}$. The upper limit for the endothermicity of this ionisation was taken to be the same as the upper limit for the activation energy of the neutral hydrolysis of CH_3I (about 30 kcal.). This fixes the upper limit of the ionisation potential of CH_3 at about 180 kcal. or 7·8 e.v. The assumption that the endothermicity of the ionisation of CH_3I in aqueous solution is the same as the activation energy of the neutral hydrolysis of CH_3I, would only be valid if the neutral hydrolysis of CH_3I proceeded by the unimolecular or S_N1 mechanism. Since, however, the neutral hydrolysis of methyl halides proceeds by a bimolecular or S_N2 mechanism[1], the activation energy of this hydrolysis will be less than the endothermicity of the ionisation reaction. (This point is discussed later). Thus, this method does not fix the upper limit of the ionisation potential of CH_3 as 7·8 e.v. As we have seen above the higher value of 10·07 e.v. is given by electron impact experiments.

(1d) Variation in Heat of Solution of R^+.

The third factor which will cause a change in the shape of the ionisation curve as the radical R is changed from CH_3 to $C(CH_3)_3$ is the heat of solution of the positive ion R^+. Heats of solution in water of positive and negative ions have been calculated by Bernal and Fowler[23] and by Eley and M. G. Evans[24]. The heat of solution of an ion can be calculated in part as an interaction between the polar water molecules in the solvation shell of the ion, and in addition the interaction of this system with the rest of the water molecules. This latter quantity is calculated as the energy of Born charging.

An estimate of the change in the heat of solution of the positive ion from CH_3^+ to $(CH_3)_3C^+$ may be made by estimating the volume of each ion, and then assigning a radius to it assuming it to be spherical. From this radius the heat of solution may be calculated by the method of Eley and M. G. Evans[24]. This has been done by considering the CH_3^+ ion to have a radius of 1·48A, the effective radius of an NH_4^+ ion, and the substituent methyl groups to have a van der Waals radius of 2·0A and a covalent radius of 0·77A. When a hydrogen atom in the CH_3^+ ion is replaced by a methyl group the resulting carbon-carbon internuclear distance has been taken as 1·54A. In this way we find the value of S^+ to decrease from 81 kcal. for CH_3^+ to 42 kcal. for $(CH_3)_3C^+$.

This method of estimating heats of solution of non-spherical ions will, however, give low values, since the relation between heat of solution and ionic radius is not linear; the increase in heat of solution with decrease in radius being more rapid the smaller the radius. The carbonium ion being planar will allow two of the four water molecules of the solvation shell to approach the central carbon atom more closely along the directions perpendicular to this plane than along directions in the plane. Thus, a better method of estimating the heat of solution of a carbonium ion is to find the effective radius of the ion in these two directions and average the heats of solution corresponding to these two radii. (The configurations of the planar methyl and *t*-butyl groups are discussed in Section 3*c* and illustrated in Figures 4 and 5.)

The radius of a singly charged carbon atom has been estimated as 0·56A[13]. For the CH_3^+ ion, if a water molecule is allowed to approach the carbon atom in a direction perpendicular to the plane of the four atoms until it touches the hydrogen atoms, the effective radius of the ion in this direction is found to be 1·0A. Along directions in the plane of the four atoms the effective radius has been taken as equal to the carbon-hydrogen covalent distance plus the hydrogen van der Waals radius, and this value is 2·29A. The heats of solution corresponding to these radii are 112·5 and 52 kcal., which give an average value of 82 kcal. This value agrees with that obtained above when the CH_3^+ radius was taken to be 1·48A.

For the $(CH_3)_3C^+$ ion if a water molecule is allowed to approach the carbon atom in a direction perpendicular to the plane of the four carbon atoms until it touches the methyl groups, the effective radius of the ion in this direction is found to be 1·15A. Along directions in the plane of the four carbon atoms the effective radius has been taken as equal to the carbon-carbon covalent distance plus the van der Waals radius of the methyl carbon atom, and this value is 3·11A. The heats of solution corresponding to these radii are 101 and 36 kcal., which give an average value of 69 kcal. This is greater than the value of 42 kcal. found by the previous method. This latter method takes account of the fact that although the volume of the ion increases from CH_3^+ to $(CH_3)_3C^+$ it does so in such a way that the approach of two of the four water molecules of the solvation shell is not greatly interfered with, and it is because of this that the second method of estimation leads to a higher value than does the first method. Although this method of estimating the heats of solution of non-spherical ions is very approximate, it indicates that the heat of solution will decrease appreciably from CH_3^+ to $(CH_3)_3C^+$. This decrease in the heat of solution of R^+ will tend to cause an increase in the endothermicity of the ionisation of $R-X$ from CH_3X to $(CH_3)_3CX$.

The heats of solution of ions in methyl and ethyl alcohol are of the same order as in water[(25)], so that the value of ΔS^+ for alcoholic solutions will be of a similar order to that estimated above.

(1*e*) *Heat of Reaction.*

We have now considered the main factors concerned in the change in endothermicity ΔQ, of the ionisation :

$$R-X_{aq} \rightarrow R^{+}_{aq}+X^{-}_{aq}$$

as R varies from CH_3 to $C(CH_3)_3$. In Table II we have listed the series of bond strengths and ionisation potentials. The heats of solution given assume that the estimated decrease of about 13 kcal. from CH_3^+ to $(CH_3)_3C^+$ occurs in equal steps along the series. The resulting values of ΔQ are given.

We see that in this series the greatest change is in the ionisation potential of the radical. The decrease in bond strength and ionisation potential along the series CH_3 to $(CH_3)_3C$,

TABLE II.

Radical	D*	I	S^+	$(D+I-S^+)$	ΔQ
CH_3	54·0	232	82	204	
CH_2CH_3	52·0	200	78	174	30
$CH(CH_3)_2$	46·5	179	74	152	22
$C(CH_3)_3$	45·0	165	69	141	11

tend to decrease the endothermicity of the ionisation reaction. This effect is opposed by the accompanying decrease in the heat of solution of the positive ion which tends to increase the endothermicity. In spite of their approximate nature, these results suggest that the endothermicity of the ionisation of $R-X$ in aqueous solution decreases as R changes from CH_3 to $(CH_3)_3C$. Further, if we assume that the activation energy of this ionisation is equal to its endothermicity (as illustrated in Figure 1[(13)]), we should expect the activation energy for the ionisation of $R-X$ in aqueous solution to decrease as R changes from CH_3 to $(CH_3)_3C$.

* The values for D given here are for the case when X is I. The changes in D with changes in R, however, will be similar for X = I, Br, and Cl

The endothermicity, and hence the activation energy, of the ionisation reaction $(CH_3)_3CX_{aq} \rightarrow (CH_3)_3C^+_{aq}+X^-_{aq}$, may be estimated with the help of the following additional data. The electron affinities of bromine and iodine are taken as 81·5 and 74·2 kcal. respectively[26]. The heats of solution of Br^- and I^- ions are taken as 58 and 46 kcal. respectively[24]. The carbon-bromine bond strength of $(CH_3)_3CBr$ is taken as 60 kcal[12]. The endothermicity of the process $(CH_3)_3\,CHal_{aq} \rightarrow (CH_3)_3\,C\,Hal_{vap}$ is not known, and for this quantity the estimated latent heat of vapourisation of the halide has been used. The values 7 and 8 kcal. have been taken for the bromide and iodide respectively. Using these data the endothermicity and hence the activation energy of the ionisation reaction is evaluated as 23·5 and 29 kcal. for *t*-butyl bromide and *t*-butyl iodide respectively. The corresponding values for the other halides are : MeBr 86·5, MeI 92, EtBr 56·5, EtI 62, *s*-PrBr 34·5, *s*-PrI 40.

If we assume that the carbon chlorine bond strength of R-Cl varies as R changes from Me to *t*-Bu in the same way as does the carbon iodine bond strength, and if we take 83·5 kcal. as the bond strength of CH_3Cl[22], 86·5 kcal. as the electron affinity of chlorine[26], 64 kcal. as the heat of solution of the chlorine ion[24], and 6 kcal. as the latent heat of vapourisation of *t*-BuCl, the endothermicity of the ionisation of RCl in aqueous solution varies according to the following sequence : MeCl 89, EtCl 59, *s*-PrCl 37, *t*-BuCl 26.

Thus, as R changes from Me to *t*-Bu the energy level of the repulsion curve $R^+_{aq}\,X^-_{aq}$ (curve *c*, Figure 1) drops with respect to the $R-X$ extension curve (curve *a*, Figure 1) and results in a marked decrease in the activation energy of the ionisation reaction.

For the methyl iodide result given above the endothermicity of the ionisation reaction is greater than the methyl iodide bond strength. Thus, according to these calculations, the CH_3I extension curve never crosses the $CH_3{}^+_{aq}\,I^-_{aq}$ repulsion curve (see Figure 2), and so, apart from energy considerations, the simple ionisation reaction in aqueous solution will be impossible in this case.

(1*f*) *Activation Energy.*

When the halide has ionised in this way, the solvated R^+ ion may react with a solvent molecule or with a negative ion and so complete a substitution reaction :—

$$R^+_{aq} + H_2O_{aq} \rightarrow ROH_{aq} + H^+_{aq}$$
$$\text{or} \quad R^+_{aq} + Y^-_{aq} \rightarrow R-Y_{aq}$$

In such a case the activation energy of the substitution reaction will be equal to the activation energy of the initial ionisation reaction. The reaction will thus be unimolecular or S_N1, and the influence of the solvent on the activation energy of the solvolysis reaction will be purely that of a solvent and not that of a reactant. Since, from the previous discussion we should expect a decrease in the activation energy for the ionisation of $R-X$ in aqueous solution as R changes from CH_3 to $C(CH_3)_3$, we should also expect a decrease in activation energy along this series for reactions of $R-X$ which are unimolecular or S_N1 in mechanism.

This expected decrease in activation energy results from a consideration of potential energy curves, and therefore refers to the absolute zero of temperature. It has been pointed out by M. G. Evans and Polanyi[27] that at a temperature T the sequence of the logarithms of the velocity constants gives a better approximation to the sequence of the activation energies at the absolute zero than does the sequence of activation energies at the temperature T. In this paper, therefore, we shall compare the activation energy sequences obtained by a consideration of potential energy curves with the sequences of the logarithms of the experimental velocity constants.

A detailed comparison of our calculated activation energies with those obtained experimentally can be made only for the change from *t*-Bu to *s*-Pr. It is found[28] that the unimolecular rates of solvolysis of *t*-butyl and *s*-propyl bromides are in the ratio $10^4 : 1$. This would correspond to a difference in activation energy of about 6 kcals. Our calculated value of 11 kcal. (Table II), is in reasonable agreement with this in view of the approximations involved in the calculation.

The unimolecular rates for tertiary and primary alkyl halides may be compared by considering *t*-butyl bromide and neopentyl bromide[29], the unimolecular rates for which are in the ratio $10^8 : 1$. This corresponds to a difference in activation energy of about 11 kcal. It is not possible to compare this with our calculated value of 33 kcal. for the change from *t*-butyl to ethyl (Table II) since the ionisation potential of the neopentyl radical is not known and may well be different from that of ethyl. The unimolecular reaction of methyl halide is so slow that it has not been observed.

We may compare the absolute values of our calculated activation energies with those obtained from experimental results as follows: the solvolysis of $(CH_3)_3CBr$ in 80 % aqueous ethyl alcohol at 55° C. is found to occur by the unimolecular S_N1 mechanism[4]. If the temperature independent factor is taken as 10^{13}sec.$^{-1}$, the velocity constant obtained corresponds to an activation energy of 22·5 kcal. The activation energy of 23·5 kcal. which was calculated in the preceding section for the ionisation of $(CH_3)_3CBr$ in aqueous solution agrees well with this value. In view of the approximations involved in this calculation, however, the very close agreement between the two values must be regarded as somewhat fortuitous.

In the unimolecular hydrolysis of *t*-butyl halide the change of halogen from Cl to Br to I results in an increase of rate which corresponds to a decrease in activation energy of about 2 kcal. from Cl to Br and a decrease of about 0·5 kcal. from Br to I[28]. The unimolecular activation energies calculated for *t*-butyl halide in Section (1*e*) show a decrease in activation energy of 2·5 kcal. from Cl to Br, which agrees well with that obtained from the experimental velocity constants. The change from Br to I, however, shows an increase of 5·5 kcal. compared with the decrease of 0·5 kcal. obtained from the experimental velocity constants.

Thus, the discussion given in this section is able to interpret fairly well those reactions of $R-X$ which Ingold and co-workers claim to be of the unimolecular S_N1 type. It is seen that as R changes from Me to *t*-Bu the effect of the decrease in $R-X$ bond strength is about sufficient to counterbalance the effect due to the decrease in the heat of solution of R^+. The great

increase in the unimolecular reaction velocity which is observed experimentally as R changes along this series is seen to be due to the very marked decrease in the ionisation potential of the radical R.

This discussion of the unimolecular ionisation of R – X differs from that previously given by Ogg and Polanyi[2c] in that these authors considered that when a change in R caused a decrease in the activation energy of the unimolecular ionisation of R – X it was due rather to a decrease in the carbon-halogen bond strength than to a decrease in the ionisation potential of R. From the present discussion, on the other hand, it appears that for the series of R, CH_3 to $C(CH_3)_3$, the change in the ionisation potential of the radical is the predominant factor.

The effect of the solvating power of the solvent on the activation energy of the unimolecular ionisation of the halide R - X can be seen from this discussion. As the solvating power of the solvent increases the potential energy curve for the solvated ions $R^{+}_{solv.}X^{-}_{solv.}$ will be displaced downwards with respect to the homopolar extension curve R –X by an amount equal to the increase in the heats of solution of the ions R^+ and X^-. This will result in a smaller R—X distance for the transition state of the ionisation reaction, and therefore a lower activation energy for this reaction

(2) BIMOLECULAR REACTIONS IN ABSENCE OF STERIC HINDRANCE.

(2a) *General Theory.*

The activation energy for the substitution reaction may often be reduced below that for the corresponding unimolecular ionisation. This is accomplished by the attack of the substituting group, solvent molecule or negative ion, at the reaction centre before the R – X bond has been elongated to the distance given by the crossing point of the two potential energy curves for R . . . X and $R^{+}_{solv.}$ . . . $X^{-}_{solv.}$, that is, the transition state distance for the unimolecular ionisation (see Figure 1). In this way the " driving force " of the bond which is to be formed is utilised in overcoming the " inertia " of the bond which is to be broken[30]. In such cases the substitution is bimolecular

and belongs to the S_N2 class of reactions These bimolecular reactions have been discussed by Ogg and Polanyi[20] and by Baughan and Polanyi[22]

For the symmetrical reaction

$$X^- + R-X \rightarrow X-R + X$$

the X R and X R distances in the transition state must be equal in order that the two resonating states

$$X \quad R - X$$

$$\text{and } X - R \quad X$$

may have equal energies Any such configuration is a possible transition state The actual transition state will be that one which has the lowest energy Baughan and Polanyi showed that a good approximation to the actual transition state could be achieved by assuming the X^- ion and the reacting carbon centre to be incompressible In this case the transition state will be obtained by bringing the X^- ion up to the reacting carbon centre until they touch, and then extending the R - X bond until the distance R X is equal to that of R X^- The activation energy for the reaction will then be equal to the energy required for this extension of the R - X bond

To find the energy of extension of the R - X bond to the transition state distance for the symmetrical bimolecular substitution reaction we need to know the potential energy curve for the R - X extension and also the distance R X in the transition state As a first approximation the R - X transition state distance which is equal to the R X^- transition state distance, may be taken as equal to the ionic radius of the halogen X^- plus the radius of the reacting carbon atom in the direction of the approaching X^- ion For this latter radius Baughan and Polanyi[22] took the covalent radius of carbon, 0 77A (This choice of radius is discussed later) The R - X distance in the transition state, assuming incompressibility of the reacting particles, is then equal to the covalent radius of carbon plus the ionic radius of the X^- ion This distance is greater than the normal R - X distance by about 0 58A, an amount which is equal to the difference between the ionic and covalent radii of the halogen[22] In the case where X is iodine this bimolecular transition state distance is 2·69A.

If the compressibility of the reacting particles is taken into account the transition state distance for the symmetrical reaction of CH_3I with iodine ions has the somewhat smaller value of about 2·6A[22]. The potential energy curve for the extension of the R – X bond in solution is shown in Figure 1 for the case of aqueous solution. Initially this curve is the extension curve for the gaseous R – X molecule, while finally it is the potential energy curve for the solvated ions $R^{+}_{solv} \ldots X^{-}_{solv}$. Its behaviour in the intermediate region is determined by the resonance between these two curves. Baughan and Polanyi assumed that for the small extension of the R – X bond required to achieve the transition state distance, resonance of the homopolar R – X curve with the solvated ionic curve is negligible. Thus, to calculate the energy of stretching of the R – X bond they employed the potential energy curve for the gaseous R – X molecule. The potential energy curve for the repulsion between the halogen ion X^- and the reacting carbon centre was taken to be the same as the repulsive portion of the Morse curve for the corresponding carbon-halogen homopolar bond. In this way Baughan and Polanyi calculated activation energies for the symmetrical substitution reactions of CH_3X, and obtained a fair agreement with the experimentally observed values.

For the reaction in aqueous solution of the symmetrical substitution :

$$I^{-}_{\alpha aq} + CH_3 - I_\beta \rightarrow I_\alpha - CH_3 + I^{-}_{\beta aq}$$

(in this equation α and β are used to differentiate between the two iodine particles), a cross-section through the potential energy surface for a constant carbon-(iodine)α distance of 2·6A (the transition state distance) is given in Figure 2. The left-hand portion of this cross-section is given by the $CH_3 - I_\beta$ extension curve *a* for the system $I^{-}_{\alpha aq}CH_3 - I_\beta$ in which the $I^{-}_{\alpha aq}CH_3$ distance is maintained constant at 2·6A. The energy of compression necessary to reduce the $I^{-}_{\alpha aq}CH_3$ distance to 2·6A is shown by the energy difference between the minimum of the $CH_3 - I_\beta$ curve *a* and the initial state of the reaction, *i*.

The right-hand portion of the cross-section is given by the $CH_3I^{-}_{\beta aq}$ repulsion curve *d* for the system $I_\alpha - CH_3I^{-}_{\beta aq}$ in which

the I_a-CH_3 distance is maintained constant at 2·6A. The repulsion sets in at a $CH_3I_\beta{}^-{}_{aq}$ distance of 2·69A. The energy of extension necessary to increase the I_a-CH_3 distance to

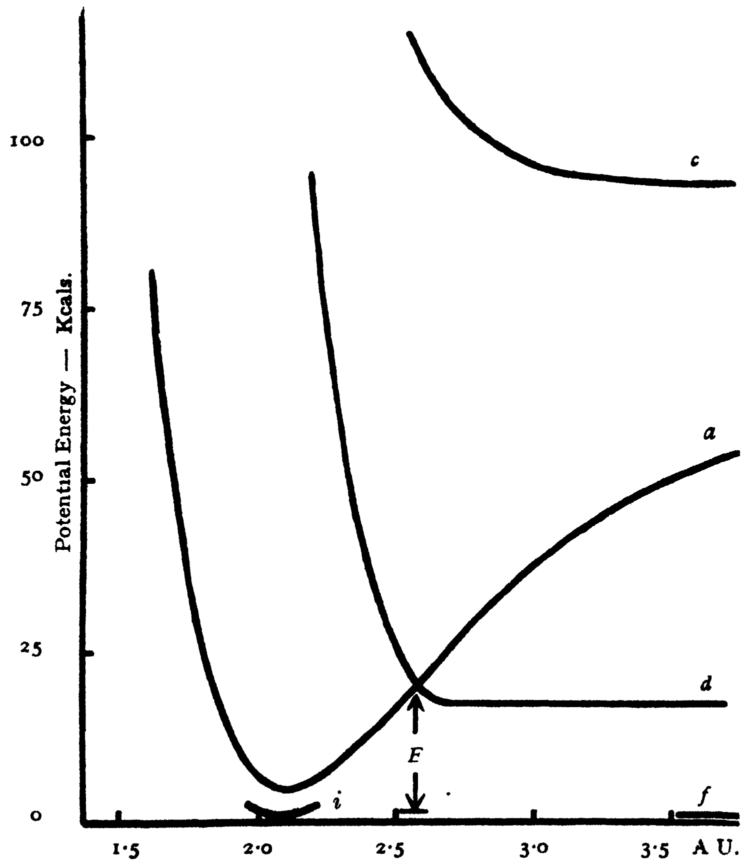


FIGURE 2

a Potential energy curve for gaseous CH_3-I_β

c Potential energy curve for solvated $CH_3{}^+{}_{aq}\ I^-{}_{\beta aq}$

d Potential energy curve for repulsion $CH_3\ I^-{}_{\beta aq}$

i Energy level of initial state $I^-{}_{aaq}+CH_3-I_{\beta aq}$

f Energy level of final state $I_a-CH_3+I^-{}_{\beta aq}$.

E is the activation energy of the reaction :

$$I^-{}_{aaq}+CH_3I_\beta \rightarrow I_aCH_3+I^-{}_{\beta aq}$$

2 6A is shown by the energy difference between the horizontal portion of the $CH_3I^-{}_{\beta aq}$ repulsion curve *d* and the final state of the reaction, *f*

It is seen from Figure 2 that the activation energy for the bimolecular reaction is practically equal to the energy of stretching the carbon halogen bond to the transition state value The activation energy for the bimolecular reaction is much less than the endothermicity of the corresponding unimolecular ionisation (the difference in energy between the minimum of curve *a* and the horizontal portion of curve *c*), and this iodine substitution reaction in aqueous solution will thus occur by the bimolecular or S_N2 mechanism

(2*b*) *Variation of Solvent*

In this simple picture of the bimolecular reaction we have not considered the effect of the solvent on the energy necessary to bring up the solvated halogen ion X to the reacting carbon atom In this process a solvent molecule will have to be removed from the solvation shell of the ion and replaced by a halide molecule The energy necessary to effect this has been discussed by Baughan and Polanyi[22], who conclude that it is of small magnitude Its magnitude, however, will increase with increase in the solvating power of the solvent This will cause an increase in the activation energy of the bimolecular reaction as the solvating power of the solvent is increased This is found in the experiments on the racemisation of iodides by iodine ions, where the addition of water to the acetone solution decreases the reaction velocity[2b]

(2*c*) *Variation of Reactant Group*

Let us compare the unsymmetrical reaction —

$$Y^- + CH_3-I \rightarrow Y-CH_3+I^-$$

with the symmetrical substitution by iodine ions illustrated by Figure 2 A smaller driving force for the unsymmetrical reaction caused, for example, by a decrease in bond strength on passing from CH_3-I to CH_3-Y, or by an increase in

solvation energy on passing from I^- to Y^-, will be indicated by the greater endothermicity of the unsymmetrical reaction. Owing to this greater endothermicity, the $CH_3I^-_{aq}$ repulsion curve will lie higher with respect to the CH_3I extension curve than will the $CH_3I^-_{aq}$ repulsion curve for the thermoneutral symmetrical reaction. Thus the methyl iodine transition state distance will be greater for this endothermic unsymmetrical reaction, and this will result in the activation energy being greater than for the symmetrical reaction. Ogg and Polanyi[2c] deduced the following theorem for these unsymmetrical reactions. As Y^- varies in such a way that the exothermicity of the substitution reaction increases then the activation energy of the reaction will decrease.

(2*d*) *Variation of Radical R.*

Let us consider the symmetrical iodine substitution reaction. This is illustrated in Figure 2 for the case when R is CH_3. If we change the radical R the endothermicity of this reaction will not change. If the change in R does not cause an increase in the steric hindrance of this bimolecular reaction the shape of the $I^-_{aq}R$ repulsion curve will also be unaltered. Any resulting change in activation energy, therefore, will be due to a change in the shape of the $R-I$ extension curve in the region below its crossing point with the I^-_{aq} R repulsion curve. A change in R which causes a reduction of the $R-I$ bond strength will lead to a flattening of the $R-I$ extension curve. The effect of such a reduction of bond strength on the energy of extension of the bond will be small for small bond extensions. This is shown in Figure 3. In this figure the potential energy diagram for the symmetrical bimolecular reaction of CH_3I is given, together with that of an iodide $R-I$ which is assumed to have a carbon-iodine bond strength which is 9 kcal. less than that of CH_3I. The Morse curve for CH_3I has been calculated using a value of 1·66 for the anharmonicity constant and a value of 55·8 kcal. for the dissociation energy of the carbon-iodine bond[22]. An approximate Morse curve for $R-I$ has been calculated using the same value for the anharmonicity constant, but a dissociation energy which is 9 kcal. less than that for CH_3I.

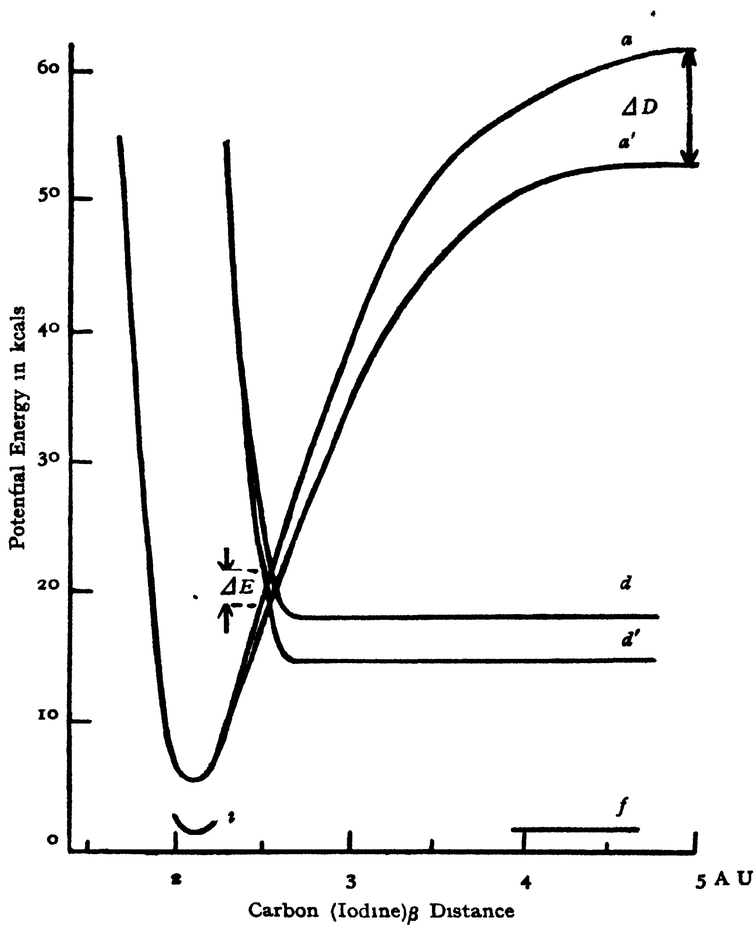


FIGURE 3

a Potential energy curve for gaseous $CH_3 - I\beta$
a' Potential energy curve for gaseous $R - I\beta$
d Potential energy curve for repulsion $CH_3\ I^{-}\beta_{aq}$
d' Potential energy curve for repulsion $R\ I^{-}\beta_{aq}$
i Energy level of initial state $I^{-}{}_{\alpha aq} + CH_3 - I\beta$ or $I^{-}{}_{\alpha aq} + R - I\beta$
f Energy level of final state $I_\alpha - CH_3 + I^{-}\beta_{aq}$ or $I_\alpha - R + I^{-}\beta_{aq}$.
Δ D is the difference in $CH_3 - I$ and $R - I$ bond strengths
Δ E is the difference between the activation energies of the reactions,

$$I^{-}{}_{\alpha\,aq} + CH_3 - I\beta \rightarrow I_\alpha - CH_3 + I^{-}\beta_{aq}$$

and $I^{-}{}_{\alpha\,aq} + R - I\beta \rightarrow I_\alpha - R + I^{-}\beta_{aq}$

This reduction in the carbon-iodine bond strength lowers the energy required to extend this bond to the transition state distance and thus causes a lowering of the $I^{-}{}_{\beta_{aq}}R$ repulsion curve with respect to the final state of the reaction. The reduction in carbon-iodine bond strength thus results in a decrease in the activation energy of the bimolecular reaction. It is seen from Figure 3 that the reduction in R – I bond strength ΔD, is greater than the resulting decrease in the bimolecular activation energy ΔE.*

An approximate relationship between the change in the carbon-halogen bond strength ΔD, and the resulting change in the bimolecular activation energy ΔE, for the symmetrical substitution reaction may be obtained in the following way. If we assume the X^{-} ion and the reacting carbon centre to be incompressible, then (as mentioned earlier) the activation energy of the symmetrical bimolecular reaction is the energy necessary to stretch the R – X bond by an amount equal to the difference between the ionic and the covalent radii of the halogen X. For the halogens Cl, Br and I, this difference in radii is about 0·58A[22]. Substitution of this extension into the Morse equation leads to the relationship : –

$$E = D\,(1 - (2e^{-a\,0.58} - e^{-2a\,0.58}))$$

between the bimolecular activation energy E, the dissociation energy D of the R – X bond, and a the anharmonicity constant of the R – X potential energy curve. An average value of a for the methyl halides may be taken as 1·66, and this leads to the expression $E = \alpha D$ where $\alpha \approx 0{\cdot}38$. Thus for a given change in R – X bond strength ΔD, the resulting change in the activation energy ΔE of the bimolecular substitution will be given by $\Delta E = \alpha \Delta D$ where $\alpha \approx 0{\cdot}38$.

We may obtain a value for α which takes into account the compressibilities of the reacting particles by finding the average of the E/D ratios for the methyl halides using the results of Baughan and Polanyi[22]. This ratio has the values 0·34, 0·33 and 0·34 for methyl chloride, bromide and iodide respectively. Thus, in the absence of steric hindrance, we should expect that for a given change in R – X bond strength ΔD, the resulting

* This was pointed out by Ogg and Polanyi[2c].

change in the activation energy ΔE of the symmetrical bimolecular substitution would be given by the relation $\Delta E = \alpha \Delta D$ where $\alpha \approx 0.3$.

An example of a change in R which causes a decrease in the R – X bond strength but which does not involve an increase in the steric hindrance of the bimolecular reaction, is the change from ethyl to allyl. It will be shown later (Section (3g)) that the steric hindrance does not increase from ethyl to allyl. The carbon-iodine bond strength decreases by 13 kcal. on changing from ethyl iodide to allyl iodide[12]. The corresponding decrease in carbon-chlorine bond strength will be of the same order. The substitution of allyl chloride by iodine ions is 38 times more rapid at 60° C. than the corresponding substitution of ethyl chloride[3a] (Table I, reaction (1)). This corresponds to a decrease in activation energy of 2·4 kcal. from ethyl to allyl. These values of ΔE and ΔD give a value of 0·2 for α compared with that obtained theoretically of about 0·3.

The change from ethyl chloride to benzyl chloride involves no increase in steric hindrance. The benzene group is flat and the carbon linking it to the reactive carbon atom has its valencies co-planar and not tetrahedral, so that in the bimolecular transition state the benzene group will not interfere with the halogens. It will be shown later that the steric hindrance does not increase from ethyl to benzyl. The carbon-iodine bond strength decreases by 8·5 kcal. from ethyl iodide to benzyl iodide[12]. The rate of reaction of R – Cl with iodine ions increases 94 fold from ethyl chloride to benzyl chloride[3a] (Table I, reaction (1)). This corresponds to a decrease in activation energy of 3·0 kcal. These values of ΔE and ΔD obtained for the change from ethyl to benzyl give a value for α of 0·35.

Although the decrease in R – X bond strength from ethyl to allyl is greater than the corresponding decrease from ethyl to benzyl, the reaction of the benzyl halide with iodine ions is more rapid than the corresponding reaction of the allyl halide. This is not in accordance with the relationship $\Delta E = \alpha \Delta D$. The same behaviour is also found for the reactions of these halides with sodium vapour[11, 12]. (Table I, reaction (11)).

For the relation $\Delta E \approx 0{\cdot}3 \Delta D$ to hold for the bimolecular reactions of R – X as R varies, it is necessary that the change

in R does not involve a marked change in the carbon-halogen internuclear distance. A change in R which lengthens the carbon-halogen separation will reduce the distance by which this bond has to be extended to achieve the transition state. Such a change in R, therefore, will tend to reduce the activation energy of the bimolecular reaction irrespective of the resulting change in the energy necessary to stretch the carbon-halogen bond.

The carbon-halogen bond distances of allyl and benzyl halides are not known. The change in the carbon-halogen bond strength of R – X associated with the change of R from Me to *t*-Bu is accompanied by no significant change in the carbon-halogen bond distance[31]. On the other hand, the carbon-halogen distances of the propargyl halides, $CH{\equiv}C-CH_2-X$, are greater than the normal single bond values by 0·07, 0·04 and 0·03A for the chloride, bromide and iodide respectively[32]. Any carbon-halogen bond lengthening which might occur in the allyl and benzyl halides, however, will probably be less than that which occurs in the propargyl halides. The high rates of the bimolecular reactions of allyl and benzyl halides may thus be partly due to a reduction in the distance by which the carbon-halogen bond has to be stretched to achieve the transition state distance, and not wholly due to the decrease in the energy necessary to extend the carbon halogen bond as assumed in the relation $\Delta E = a\Delta D$.

(3) Bimolecular reactions involving steric hindrance

(3*a*) *General Theory.*

The variation of R along the series Me, Et, *s*-Pr and *t*-Bu has an effect on the behaviour of the halides R – X which is in marked contrast to that discussed in the previous section. Along this series from Me to *t*-Bu there is a decrease in R – X bond strength of about 9 kcal[12]. This decrease in R – X bond strength is accompanied by an increase in the rate of reaction of these halides with sodium vapour (Table I, reaction (11)). The bimolecular reaction rates of these halides with negative ions, on the other hand, show a decrease along this series

(Table I, reactions (1) and (5)). Thus the relationship between ΔE and ΔD for the bimolecular reactions of this series of $R-X$ is opposite in sign to that derived for bimolecular reactions in the preceding section. It has been suggested that along this series the decrease in $R-X$ bond strength is accompanied by an increase in the steric hindrance of the bimolecular reaction, which outbalances the effect due to the weakened bond[2a, 2c, 33].

(3b) Method of Assessing Steric Hindrance.

The activation energy of the reaction $X^- + R-X \rightarrow X-R + X^-$ will be made up of three terms: (1) the energy to extend the $R-X$ bond from its normal distance to that of the transition state, (2) the energy to bring the three carbon valencies into a plane, and (3) the energy to bring up an X^- ion to the transition state distance from the reacting carbon atom. Baughan and Polanyi[22] considered these reactions for the case when R was CH_3. They assumed that the energy required to bring the three carbon valencies into a plane was zero; that is, they assumed no steric interference between the halogen X and the groups attached to the central carbon atom when these groups were co-planar with the reacting carbon atom. For the repulsion energy curve X^- CH_3 they took the repulsion part of the Morse curve for the gaseous CH_3-X molecule. Here again, then, the steric interference between the halogen ion X^- and the groups attached to the central carbon atom when these are co-planar has been neglected. The transition state distances, therefore, which they calculate are for zero steric interference between substituent groups and halogens.

If we use these transition state distances for various groups R, then in cases of zero steric effect the internuclear distance between either of the halogens and any atom other than the reacting carbon atom must be greater than the sum of the van der Waals radii of the atoms concerned. In cases where any internuclear distance determined in this way between the halogen and a non-reacting atom is less than the corresponding van der Waals distance, the activation energy of the reaction will be increased due to steric hindrance. The difference between these two distances may be taken as a measure of the steric

effect of the groups involved. In this way the increase in the steric hindrance to reaction along the series of R : CH_3, CH_2CH_3, $CH(CH_3)_2$, $C(CH_3)_3$, for the symmetrical substitution :

$$X^- + R - X \longrightarrow X - R + X^-$$

has been estimated by A. G. Evans and M. Polanyi[33].

To calculate the required distances the rectangular co-ordinates of the atoms in the transition state were found. The reacting carbon atom of the radical R was taken as the origin ; the three atoms joined to this atom and co-planar with it were placed in the YZ plane, and the halogens were placed on the positive and negative X axes at the transition state distances found for the case of CH_3. In this way the lines joining the centres of each halogen with the centre of the reactive carbon atom are perpendicular to the plane containing the reactive carbon atom and the three atoms directly attached to it.

This fixes the positions of the halogens, the reacting carbon atom and the three atoms attached to it. The position of the other atoms in the transition state is not thereby determined because of the possibility of rotation about bonds. The position of these other atoms was determined by finding the configuration for which there was the least steric effect, and for which there was complete symmetry about the YZ plane. These two conditions could be simultaneously fulfilled. The following distances were used* : van der Waals radii : C 1·57, H 1·2, Cl 1·8, I 2·15 ; bond distances : C – C 1·54, C – H 1·09, C – Cl 2·34, C – I 2·68. These last two distances are those calculated by Baughan and Polanyi[22] for the transition states of the symmetrical reactions when R is CH_3, assuming the reacting particles to be incompressible. The actual transition state distances will be shorter than these by about 0·1A. The angle between the carbon valencies was taken as the tetrahedral angle 109° 28′, except in the case of the reacting carbon atom, where the three valencies were taken as co-planar and at an angle of 120° to each other.

* These distances are taken from " The Nature of the Chemical Bond," Pauling (Cornell University Press), 1939. The van der Waals radius for an aliphatic carbon atom has been taken as 0·8A greater than the single bond covalent radius of carbon, according to the general rule suggested by Pauling.

In two of the radicals R investigated the three groups attached to the reacting carbon atom were not of the same size. The effect on the internuclear distances of bending the carbon halogen bonds away from the larger groups has been determined for different angles of bending. The larger groups were placed on the positive Z side of the XY plane, and the carbon halogen bonds were bent in the XZ plane towards the negative Z axis.

(3*c*) *Steric Hindrance in Series Me to t-Bu.*

When the hydrogen atoms of the methyl group were made co-planar with the carbon atom and the chlorines were placed at the transition state distances calculated by Baughan and Polanyi, the hydrogen-chlorine distances were found to be 2·58A. This distance is 0·42A less than the corresponding van der Waals distance of 3·0A. The chlorine and hydrogen atoms, however, are linked to the same carbon atom. Pauling[34] has discussed the fact that atoms which are bonded to the same atom can approach one another much more closely than the sum of the van der Waals radii, and he concludes that the non-bonded radius of an atom in directions close to the bond direction (within 35°) is about 0·5A less than the van der Waals radius. In the case of the planar methyl group and the chlorine discussed above, the line joining the chlorine and hydrogen centres makes an angle of 25° with the carbon-chlorine bond and an angle of 65° with the carbon hydrogen bond. If the van der Waals radius of chlorine is shortened accordingly by 0·5A, the van der Waals distance for chlorine-hydrogen becomes 2·5A. This is slightly less than the value calculated above of 2·58A, and so it appears probable that in the case of the methyl group the hydrogen atoms do not interfere sterically with the halogen atom.

The chlorine ion, however, is spherically symmetrical with a radius of 1·8A, and will thus interfere with the hydrogen atoms in the transition state.

The transition state configuration of the methyl group is shown in Figure 4. The triangular area indicates the reacting carbon atom with its three co-planar valencies joining it to the hydrogen atoms which are represented by the semi-circular

areas. The four atoms are co-planar. In the transition state one of the chlorines is situated on the near side and one on the far side of this plane, in such a way that the lines joining the carbon and chlorine centres are perpendicular to this plane.

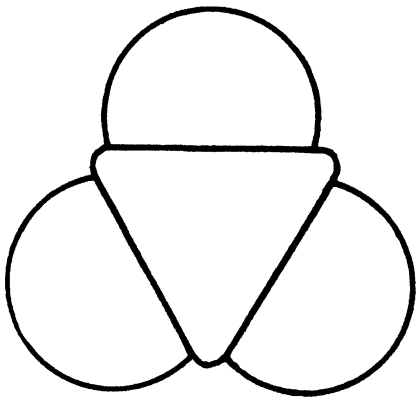


FIGURE 4.
Transition state configuration of methyl group.

If we replace the three hydrogen atoms of CH_3 by methyl groups to give $C(CH_3)_3$, the arrangement of the atoms of the $C(CH_3)_3$ group in the transition state is shown in Figure 5. The black areas indicate the normal carbon atoms, the white areas indicate the hydrogen atoms. The central reacting carbon atom with its three co-planar valencies joining it to the three methyl groups has been left white. It is seen that one of the hydrogen atoms of each methyl group is co-planar with the four carbon atoms. The other two hydrogens of each methyl group project out from this plane, one on each side. In the figure this plane has been drawn at a slight angle to the plane of the paper so that the hydrogen atoms on the far side may be seen. If we now place the chlorine particles at distances from the reacting carbon atom equal to those found for the transition state when R is CH_3, we find the distance between the chlorine and the β-carbon atoms to be 2·8A. This is 0·57A less than the normal van der Waals distance. Since the line joining the β-carbon and chlorine centres makes an angle of 33° with

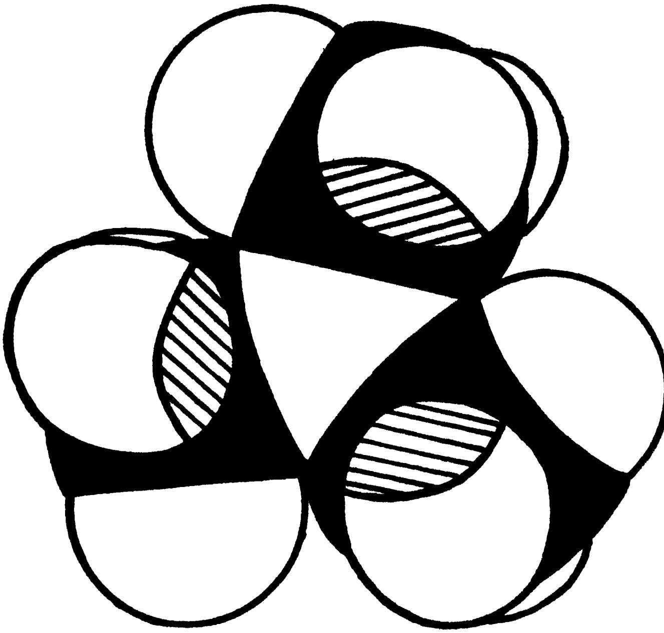


FIGURE 5

Transition state configuration of *t*-butyl group

the α-carbon-chlorine bond, and an angle of 57° with the α-carbon-β-carbon bond, the β-carbon-chlorine van der Waals distance will be less than the normal value by about 0·5A. This will result in a small compression of about 0·07A between the chlorine and the carbon. The distance between the centres of the projecting hydrogen and the chlorine is calculated as 2·44A. Since the hydrogen and chlorine are now not joined to the same atom, and since the line joining their centres makes angles greater than 50° with the bonds concerned, the van der Waals distance for this chlorine hydrogen pair will be 3·0A. This results in a compression of 0·56A between the chlorine and the projecting hydrogen[33]. In Figure 5 the three hydrogen atoms projecting on the near side of the carbon plane are shaded where they will suffer penetration by the chlorine atom when this is placed at its transition state distance from the central carbon atom. The chlorine ion is spherically symmetrical and will interfere strongly with the carbon atoms as well as with the hydrogen atoms in the transition state.

The transition state arrangement of the atoms of the groups $CH(CH_3)_2$ and CH_2CH_3 is the same as shown in Figure 5 for $C(CH_3)_3$ except that one and two methyl groups are replaced by hydrogen atoms respectively. The steric effect thus decreases along the series $C(CH_3)_3$, $CH(CH_3)_2$, CH_2CH_3, CH_3 partly by the reduction in the number of points of obstruction, and partly by the possibility of avoiding obstruction by a bending of the carbon chlorine bond away from the methyl groups. This method of avoiding obstruction is not available for the case of $C(CH_3)_3$ where the three substituent groups are identical, since any bending of the carbon chlorine bond here brings the chlorine still closer to a methyl group. The bending of the carbon chlorine bond to avoid obstruction is more effective for CH_2CH_3 than for $CH(CH_3)_2$, since in CH_2CH_3 the carbon chlorine bond is bent directly away from the single methyl group, whereas in $CH(CH_3)_2$ there are two substituent methyl groups to bend away from. For the case of CH_2CH_3 the chlorine hydrogen interpenetration can be practically reduced to zero by bending the carbon chlorine bond through an angle of 18°. The compressions found for iodine are slightly greater, by about 0·1A, than those obtained for chlorine.

In this Me to *t*-Bu series there is no steric interference between the groups in the normal tetrahedral molecule.

The method used above definitely shows the presence of increasing steric hindrance along the series of R from CH_3 to $C(CH_3)_3$ provided that the transition state distance of R . . . X found for the case when R is CH_3 is correct. The determination of this distance requires a knowledge of the repulsion curve between the halogen ion X^- and the reacting carbon centre. For this repulsion curve Baughan and Polanyi[22] used the repulsive portion of the Morse curve for the corresponding carbon-halogen homopolar bond. This is a steep repulsion curve.

Baughan and Polanyi considered that repulsion between the halogen ion and the reacting carbon centre will begin at a carbon halogen distance which is greater than the corresponding covalent distance by an amount equal to the difference

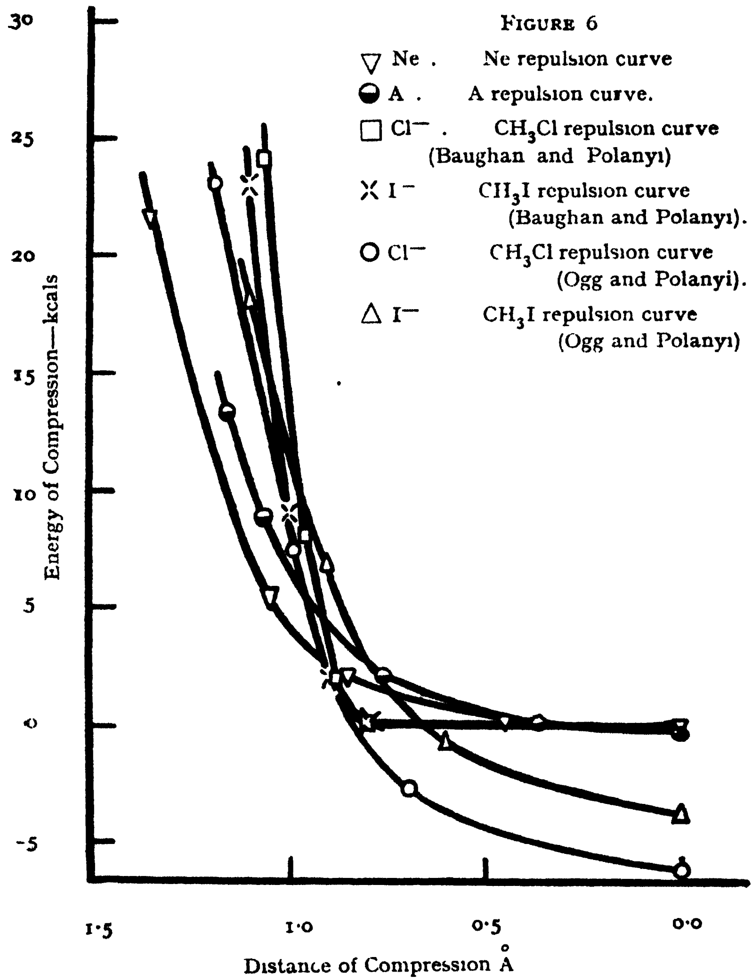
between the ionic and covalent radii of the halogen. This, however, is not so. These authors have not allowed for the greater radius of the carbon atom in the non-bonded direction compared with that in the bonded direction. This difference between the van der Waals and the covalent radius of carbon will be about 0·8A. Thus the distance between the reacting carbon atom and the halogen ion at which Baughan and Polanyi consider repulsion to begin is about 0·8A less than the van der Waals distance between these particles.

We have plotted the energy curves for the repulsion between two neon atoms and between two argon atoms using the formula $E(r) = -\mu r^{-6} + Pe^{-r/\rho}$ and the corresponding constants given by Buckingham[35]. These repulsion curves, which are given in Figure 6, show that as the internuclear separation is reduced below the van der Waals distance the energy of compression is small initially, but as the compression increases beyond about 0·8A, a steep rise in the repulsion curve occurs.

In Figure 6 the repulsion curves used by Baughan and Polanyi are given. The repulsion begins at a compression of 0·8A. These curves show a marked similarity of shape to those for the inert gases.

We have also included in Figure 6 the repulsion curves used by Ogg and Polanyi in their earlier treatment of this problem[26]. These curves involve (*a*) the interchange repulsion between the halogen ion and the carbon centre, (*b*) the attraction between the charge on the halogen ion and the carbon-halogen dipole, and (*c*) the attraction due to the polarisation of the carbon atom in the field of the ionic charge. In the region for which these curves show a negative repulsion energy, the attraction due to the ion-dipole interaction is the predominant factor. In the region for which these curves show a positive repulsion energy, their shape is similar to those used by Baughan and Polanyi.

We have calculated the activation energies E, and the transition state distances r, for the reactions of Cl^- with CH_3Cl and of I^- with CH_3I by the method of Baughan and Polanyi using the repulsion curves of Ogg and Polanyi. We find $E \approx 26$ kcal., $r \approx 2{\cdot}1$A for the CH_3Cl reaction and $E \approx 23$ kcal.,



$r \approx 2{\cdot}5$A for the CH_3I reaction. The corresponding values found by Baughan and Polanyi are $E=28$ kcal., $r=2{\cdot}2$A for the CH_3Cl reaction, and $E=19$ kcal. and $r=2{\cdot}6$A for the CH_3I reaction. Thus the use of the Ogg and Polanyi repulsion curves reduces the transition state distances slightly and also reduces to some extent the range of variation of the activation energy with change of the halogen.

Thus, although Baughan and Polanyi have considered repulsion between the halogen ion and carbon centre to begin at a distance which is about 0·8A less than the corresponding van der Waals distance, it appears from the above discussion that the steep repulsion assumed by Baughan and Polanyi will in fact not occur until the internuclear separation is reduced below the van der Waals distance by about 0·8A. Since the main function of the X^- . . . R repulsion curve in the determination of the transition state distance of $R-X$ is to indicate the X^- . . . R distance at which compression becomes difficult, we may conclude that the repulsion curves as used by Baughan and Polanyi are reasonable approximations.

(3*d*) *Effect of Steric Hindrance on Activation Energies.*

We can discuss the effect of steric hindrance on the activation energy of the bimolecular reaction by considering the reaction :—

$$I^-_{\alpha}+CH_3-I_{\beta} \longrightarrow I_{\alpha}-CH_3+I^-_{\beta}$$

the energy diagram for which is given in Figure 2. Since in the transition state the central carbon atom and the three groups joined to it are co-planar, the curves required for CH_3-I_{β} extension and CH_3 I^-_{β} repulsion are those for which the four atoms of the CH_3 group are co-planar. Since bringing the three hydrogens into the same plane as the carbon does not cause much steric interference between these atoms and the halogen it is satisfactory to use for these potential energy curves the attractive and repulsive portions of the energy curve for gaseous CH_3-I in which the carbon valencies are tetrahedral. If the hydrogen atoms were substituted by large groups, then assuming these substituents had no effect on the carbon-iodine bond strength, the activation energy of the bimolecular reaction would be increased. The $R-I_{\beta}$ extension curve required for the potential energy diagram would be that in which the central carbon atom and the three non-reacting groups attached to it were co-planar. This would raise the $R-I_{\beta}$ extension curve above that for CH_3-I_{β} for carbon iodine distances where steric hindrance occurred. The RI^-_{β} repulsion curve required would also be that in which R had the co-planar transition state configuration. This would raise the RI^-_{β} repulsion curve above

that for $CH_3\ I^-{}_\beta$ over the range of carbon iodine distances where steric hindrance occurred. These changes would result in the extension and repulsion curves crossing at a higher energy, and would thus lead to an increased activation energy.

The increase in the activation energy of substitution due to steric hindrance will be minimised by the distribution of this energy among the various possible degrees of freedom. Thus the introduction of an obstructing group on to the reacting carbon atom will cause an increase in the bimolecular activation energy partly due to the increase in the carbon-halogen transition state distance, partly due to the compression of the halogen against the obstructing group and partly due, if possible, to the bending of the carbon-halogen bond away from the obstructing group.

The energy of bending the carbon-halogen bond is difficult to assess directly. This energy may be estimated in various ways. For carbon-carbon bonds the angle $C-\hat{C}-C$ increases from 60° in cyclopropane through 90° in cyclobutane and 108° in cyclopentane to the normal tetrahedral angle of 109° 28′ in the unstrained cyclohexane molecule. This increase in angle is accompanied by an increase in the heat of combustion of these compounds when expressed as kcal. per CH_2 group. From these heats of combustion, according to Branch and Calvin, the energies required to decrease the angle $C-\hat{C}-C$ below its normal value by 1° 28′, 19° 28′, and 49° 28′ are found to be 1, 4, and 10 kcal. respectively[36].

The bond orbitals of carbon are sp^3 hydrids. The bond orbital in the Z direction is :

$$f_z = \tfrac{1}{2}+\tfrac{3}{2}\cos\theta,$$

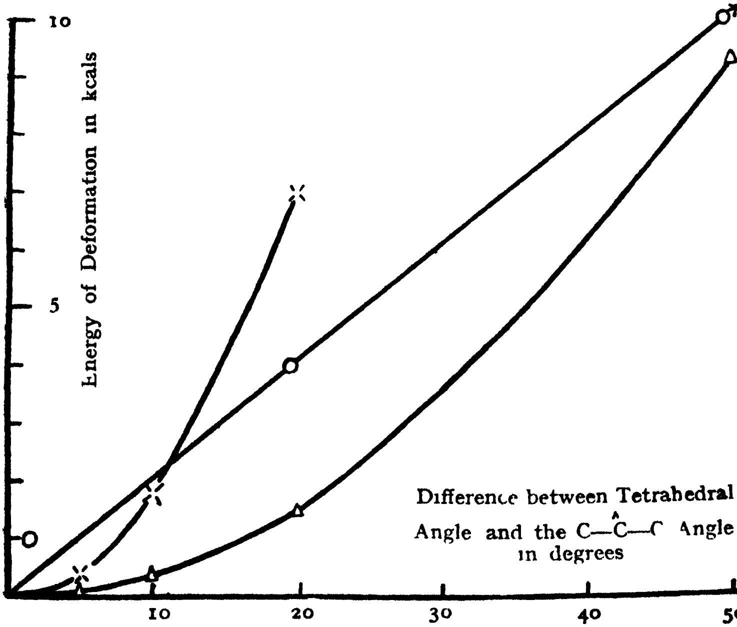
where θ is the angle measured from the Z axis (ref. 34, p. 86). The interchange energy J of the carbon-carbon bonds in the cyclic compounds just discussed may be taken as proportional to $(\tfrac{1}{2}+\tfrac{3}{2}\cos\theta)^2$, where θ is the angle between the actual bond direction and the normal bond direction. In this case the angle $C-\hat{C}-C$ will differ from the tetrahedral angle by 2θ. When θ is zero, the interchange energy is equal to the normal value J_0. Thus J is equal to $\frac{J_0}{4}(\tfrac{1}{2}+\tfrac{3}{2}\cos\theta)^2$. If we take the

FIGURE 7.

O Calculated from heat of combustion data.

△ Calculated from $\frac{J_0}{4}(\frac{1}{3}+\frac{2}{3}\cos\theta)^2$

X Calculated from the deformation constant



carbon-carbon unstrained bond strength as 85 kcal., and take 80 % of this as interchange energy, we find that the energies required to decrease the C–Ĉ–C angle below the normal tetrahedral angle by 5°, 10°, 20° and 50° are 0·1, 0·4, 1·5 and 9·3 kcal. respectively.

Another method of estimating the energy required to decrease the C–Ĉ–C angle is to use the corresponding deformation constant. For propane the deformation constant is given as $0.335.10^5$ dynes/cm[37]. Using this constant it is found that the energies required to reduce the C–Ĉ–C angle by 5°, 10°, and 20° are 0·4, 1·8, and 7·0 kcal. respectively. The energy curves obtained by these three methods are shown in Figure 7. There is not a good agreement between these different estimations. It is seen, however, that the energy required for the bending of a bond is not large in the initial stages.

In the case when R is CH_2CH_3 there are two methods of avoiding chlorine-methyl interpenetration in the transition state : (*a*) by bending the carbon-chlorine bond through an angle of 18° away from the methyl group, or (*b*) by increasing the carbon-chlorine transition state distance from 2·34A to 3·15A. According to Figure 7 method (*a*) will involve an energy of the order of 2 to 6 kcal. Method (*b*) will involve an energy of the order of 35 kcal. Thus, the replacement of a hydrogen atom in CH_3Cl by a CH_3 group will scarcely affect the carbon-chlorine transition state distance for the symmetrical substitution reaction ; the main result will probably be the bending of the carbon-chlorine bond.

A simplification is introduced by considering the case of $C(CH_3)_3$ where the avoidance of obstruction by bending the carbon-chlorine bond is impossible. The symmetrical reaction of $R-I$ with iodine ions will be affected by two factors when R is changed from CH_3 to $C(CH_3)_3$. There will be (*a*) a decrease in the carbon-iodine bond strength, and (*b*) an increase in steric hindrance. We have drawn an approximate energy curve for the extension of the carbon-iodine bond in $(CH_3)_3\,C-I$. The carbon-iodine equilibrium distance has been taken as equal to that in CH_3I. This assumption is justified by the fact that the carbon-chlorine and carbon-bromine distances in the *t*-butyl halides are not significantly different from those in the methyl halides[31]. The energy of dissociation of the carbon-iodine bond has been taken as 9·0 kcal. smaller than that of CH_3I[12]. The anharmonicity constant has been assumed to be the same as that for CH_3I[22]. The repulsion curve for $(CH_3)_3\,C\,.\,.\,.\,I^-$ in the absence of steric hindrance has been taken as the same as the repulsive portion of the CH_3-I Morse curve, and the radius of the reacting carbon atom has been taken as 0·77A, as in the Baughan and Polanyi method. Using these curves, we have drawn cross-sections through the potential energy surface for the reaction :

$$I_\alpha^- + (CH_3)_3\,C-I_\beta \longrightarrow I_\alpha - C(CH_3)_3 + I_\beta^-$$

for different carbon-(iodine)α distances and found the minimum energy for the transition state of this reaction in the absence of steric hindrance. It was found that the carbon-iodine

transition state distance was 2·6A, which is the same as when R is CH_3. This was expected (see Figure 3). It was found that the activation energy was 16 kcal. This is 3 kcal. less than the value of 19 kcal. obtained by Baughan and Polanyi for the CH_3I reaction[22]. This, also, was expected since, as we have seen, $\Delta E \approx 0{\cdot}3\, \Delta D$. Thus the decrease in carbon-iodine bond strength from methyl to *t*-butyl iodide will tend to lower the activation energy of the bimolecular reaction with iodine ions.

An attempt has been made to calculate the activation energy of the reaction of $(CH_3)_3CI$ with I^- ions taking into account the steric repulsions between the iodines and the methyl groups as well as the small carbon-iodine bond strength. This attempt can only be very approximate. On one side of the central carbon plane there is an iodine ion which is spherically symmetrical, while on the other side there is a bonded iodine atom which is not spherically symmetrical, but which tapers down in some way in the direction of the central carbon atom. The iodine atom interferes only with the hydrogens of the methyl groups, while the iodine ion interferes with the methyl carbon atoms as well as with the hydrogens. In estimating the repulsion energy we have treated the methyl group as a whole and calculated the methyl-iodine repulsion.

The repulsion energy between the methyl group and the iodine ion has been assumed to be of the form $R = -\dfrac{\alpha e^2}{2r^4} + br^{-9}$ where α is the polarisability of the methyl group in the combined state. The constant b is determined by the condition that $\dfrac{dR}{dr} = 0$ when $r = r_0$, the normal distance between a methyl group and an iodine ion. This distance has been taken as the sum of the radii of the two. The methyl group has been assumed to have the radius 1·57A. This is the van der Waals radius of carbon, and has been used because the relative positions of the carbon, hydrogen and halogen ion in the transition state are such that the compression between the halogen ion and the hydrogen is the same as that between the halogen ion and the carbon (see Section (3*c*)). The radius of the iodine ion has been taken as 2·15A[34]. The polarisability of the methyl group α has been taken as $2.22.10^{-24}$ cc.

The repulsion between a methyl group and an iodine atom will be greater than that between a methyl group and an iodine ion, because of the absence in the former case of the polarisability term. We have, however, taken the repulsion between the methyl group and the iodine ion as a lower limit for the repulsion between the methyl group and the iodine atom, because of the uncertainty in the calculation of the van der Waals attraction in the latter case.

Using this method of estimating the methyl-iodine repulsions we have recalculated the activation energy of the reaction of $(CH_3)_3CI$ with iodine ions. We find a value of about 21 kcal. for the activation energy of this reaction. This value is about 2 kcal. greater than that calculated for CH_3I[22]. It appears, therefore, that the steric repulsions caused by introducing methyl groups on to the reacting carbon atom, are sufficient to produce an increase in the activation energy of the bimolecular reaction, even though the presence of these methyl groups results in a decrease in the carbon-iodine bond strength, which causes a decrease in the activation energy of the sterically unhindered reaction of the halide with sodium vapour.

(3*e*) *Conditions which determine the Reaction Mechanism.*

In Section (1*e*) we derived a sequence of activation energies for the hydrolyses of methyl, ethyl, *s*-propyl and *t*-butyl halides assuming that the mechanism of these hydrolyses was the unimolecular S_N1 type. In accordance with this mechanism it was assumed that in the initial rate determining ionisation of the halide $R-X$, the water molecules and the carbonium ion R^+ attracted each other by ion-dipole attractive forces only; the formation of a co-ordinate link between the water molecule and the ion was considered not to occur at this stage.

In discussing this question Ogg[38] has compared the endothermicities of the two reactions:

$$\text{R Hal}_{aq} = \text{R}^+{}_{aq} + \text{Hal}^-{}_{aq} \quad \ldots \ldots \ldots \ldots \quad (1)$$

and

$$\text{H}_2\text{O}_{aq} + \text{R Hal}_{aq} = \text{H}_2\text{O}^+ \rightarrow \text{R}_{aq} + \text{Hal}^-{}_{aq} \quad \ldots \quad (2)$$

for the cases when R is methyl and ethyl. Ogg calculates that reaction (1) (in which there is no co-ordinate link between the water molecule and the carbonium ion), is of the order of

50—70 kcal. endothermic whereas reaction (2) is about thermoneutral. From this he concludes that it is impossible for reaction (1) to occur and that ionisation reactions do not involve the formation of a carbonium ion with an " open sextet " but are essentially bimolecular reactions of the type of reaction (2).

By our calculations (Section (1*e*)) we find the endothermicity of reaction (1) to be 89, 86·5, and 92 for CH_3Cl, CH_3Br, and CH_3I, and 59, 56·5 and 62 for C_2H_5Cl, C_2H_5Br and C_2H_5I respectively, and would thus agree with Ogg that the hydrolyses of these halides will not occur by the unimolecular S_N1 mechanism. Ingold and co-workers, however, have not claimed that the hydrolyses of methyl and ethyl halides in aqueous solution are of the unimolecular mechanism. According to these authors it is the secondary and tertiary halides which may react by the unimolecular S_N1 mechanism. In Section (1*e*) we calculated the following values for the activation energy of reaction (1): 37, 34·5 and 40 kcal. for *s*-propyl chloride, bromide and iodide, and 26, 23·5 and 29 kcal. for *t*-butyl chloride, bromide and iodide. These results were discussed in Section (1*f*) and were shown to agree fairly well, except for the iodides, with those obtained experimentally for reactions of $R-X$ which Ingold and co-workers claim to be of the unimolecular S_N1 type. Thus for *s*-propyl and *t*-butyl halides it is possible to account for the rates of reaction on the basis of the unimolecular mechanism established by Ingold and co-workers. To prove from first principles that under certain conditions the hydrolysis of *s*-propyl and *t*-butyl halides proceeds by the unimolecular S_N1 mechanism (reaction (1)) and not by the bimolecular S_N2 mechanism (reaction (2)), it would be necessary to calculate the activation energy of the bimolecular reaction and compare it with that of the unimolecular reaction. This, however, could not be done with sufficient accuracy to decide the matter, and so we shall discuss this question in a more general way.

The bimolecular reaction (2) is a thermoneutral reaction according to Ogg[38], and so will have an energy diagram similar in type to that given in Figure 2 for the thermoneutral bimolecular reaction $I^- + CH_3I$. The minimum of the $R-Hal$ extension curve *a* will lie above the energy level of the initial

state of the reaction *i*, by the amount of energy necessary to reduce the distance between H_2O and R Hal to the transition state value. The horizontal portion of the curve *d* for the repulsion between $H_2O^+ \rightarrow R$ and Hal^- will lie above the energy level of the final state of the reaction *f*, by the amount of energy necessary to extend the $H_2O^+ \rightarrow R$ bond to its transition state distance. The activation energy of the bimolecular reaction will be given by the energy difference between the initial state *i* and the crossing point of the extension curve *a* and the repulsion curve *d*. The activation energy of the unimolecular reaction will be given by the energy difference between the minimum of the R Hal extension curve *a* and the horizontal portion of the R^+_{aq} Hal^-_{aq} repulsion curve *c*.

When R is CH_3 the activation energy of the bimolecular reaction will be much less than that of the unimolecular reaction, as can be seen in Figure 2. As R changes from Me to *t*-Bu the R^+_{aq} Hal^-_{aq} repulsion curve *c* drops markedly with respect to the R – Hal extension curve *a*. As discussed in Section (1*f*) this pronounced drop, which is due to the decrease in the ionisation potential of the radical from Me to *t*-Bu, will result in a fall of about 63 kcal. in the activation energy of the unimolecular reaction of R – X as R changes from Me to *t*-Bu. In the absence of steric hindrance the activation energy of the bimolecular reaction would be reduced as R changes from Me to *t*-Bu according to the relation $\Delta E = \alpha \Delta D$, as discussed in Section (2*d*), and illustrated in Figure 3. The decrease in R – Hal bond strength ΔD as R changes from Me to *t*-Bu is about 9 kcal[12], and the corresponding reduction in the bimolecular activation energy ΔE would only be a fraction of this, even in the absence of steric hindrance. Since there is an increase of steric hindrance from Me to *t*-Bu the bimolecular activation energy will tend to increase along this series. Thus, although for Me Hal the activation energy of the unimolecular reaction is much greater than that of the bimolecular reaction, as the halide changes from methyl to *t*-butyl the activation energy of the unimolecular reaction will fall rapidly while that of the bimolecular reaction will rise more slowly (the increase in steric hindrance being opposed by the decrease in the R – X bond strength).

Another way of looking at the convergence of the unimolecular and bimolecular activation energies as R changes from Me to *t*-Bu is the following. As discussed later (Section (5*a*)), a low ionisation potential of the radical R means a high resonance energy of the ion R^+. This resonance, which results from the fact that the positive charge can occupy various positions in the ion R^+, will no longer be possible if the positive carbonium ion completes its octet by co-ordination. Thus the large decrease in the ionisation potential of the radical R as it changes from Me to *t*-Bu will cause a large increase in the " driving force " of positive ion formation in the unimolecular reaction, but will have no effect on the " driving force " of bond formation in the bimolecular reaction.

We may now discuss the way in which the mechanism of the reaction of R – X is affected as the difference between the unimolecular and bimolecular activation energies is reduced on changing from Me to *t*-Bu.

There are two factors which will determine whether the reaction :

$$Y^- + R - X \longrightarrow Y - R + X^-$$

is unimolecular or bimolecular ; (*a*) the activation energies of the unimolecular and the bimolecular mechanisms, and (*b*) the concentration of the reactant Y^-. The velocities of the unimolecular and bimolecular reactions may be written

$$V_u = A_u \,.\, e^{\frac{-E_u}{RT}} [RX].$$

and $$V_b = A_b \,.\, e^{\frac{-E_b}{RT}} [RX]\,[Y^-]$$

respectively. The condition that the bimolecular velocity is 10 times that of the unimolecular velocity is :

$$(E_u - E_b) = 2{\cdot}303 \text{ R.T.} \left(1 + \log_{10} \frac{A_u}{A_b} - \log_{10} [Y^-]\right).$$

Taking $\frac{A_u}{A_b}$ as $10^{13}/10^{14}$ moles. cc.$^{-1}$ and the concentration of Y^- as M/10, this condition becomes $(E_u - E_b) = 5{\cdot}5$ kcal. This means that when the concentration of Y^- is M/10 the substitution reaction will be substantially bimolecular (90 %) only if the bimolecular activation energy is less than the unimolecular activation energy by 5·5 kcal. or more.

For the hydrolysis of $R-X$ in pure water, if we take the concentration of water as $55.5 . 10^{-3}$ moles. cc^{-1}., the hydrolysis will be substantially bimolecular only if the bimolecular activation energy is less than the unimolecular activation energy by 1·7 kcal. or more.

Using the same equations we find that if the unimolecular and bimolecular activation energies are equal, the ratio of the unimolecular to bimolecular reaction velocities is 1000 when the concentration of Y^- is $M/10$, and is about 2 when the concentration of reactant is $55.5 . 10^{-3}$ moles. $cc.^{-1}$.

Thus the rate of the bimolecular reaction is dependent on the concentration of the reactant Y^- as well as on the activation energy of the reaction. As the difference between the unimolecular and bimolecular activation energies is reduced, therefore, the reaction mechanism will cease to be substantially bimolecular even while the unimolecular activation energy is still greater than the bimolecular activation energy.

Since the activation energy of the unimolecular reaction falls rapidly, while that of the bimolecular reaction rises slowly, one might expect that in certain cases the activation energy for the unimolecular reaction would be less than that for the bimolecular reaction. Consideration of this problem, however, shows that the activation energy of the bimolecular reaction can never be greater than that of the unimolecular reaction. Let us consider the symmetrical reaction $I_\alpha^- + R - I\beta$. Any configuration in which the two carbon-iodine distances are equal is a possible bimolecular transition state. The actual bimolecular transition state is that one for which the energy is a minimum. Suppose the carbon-(iodine)$_\beta$ distance for the unimolecular transition state is u. Then, starting with the carbon-(iodine)$_\beta$ distance as b, $(b<u)$, if the non-reacting groups of R can be made co-planar with the reacting carbon atom and the ion I_α^- brought up so that the carbon-(iodine)$_\alpha$ distance is also b, with less energy than that necessary to stretch the carbon-(iodine)$_\beta$ bond of the single molecule from b to u, then the bimolecular reaction will have less activation energy than will the unimolecular reaction. Due to the fact that the unimolecular transition state distance is small, or that appreciable steric hindrance is present, it may be that to mak

the non-reacting groups of R co-planar with the reacting carbon atom (with the carbon-(iodine)$_\beta$ distance equal to b) and to bring up the ion I_α^- to a carbon-(iodine)$_\alpha$ distance of b, will require a greater energy than that necessary to extend the carbon-(iodine)$_\beta$ bond of the single molecule from b to u for all distances of $b<u$. In this case the system having the minimum energy when the two carbon-iodine distances are equal (which is a necessary condition for the actual bimolecular transition state) will have a carbon-iodine distance which is greater than that of the unimolecular transition state. The activation energies of the bimolecular and unimolecular reactions will thus be the same, but the reaction will be unimolecular in mechanism, since the interaction of I_α^- with the reacting carbon atom will be able to lower the energy of the system only after the unimolecular ionisation of $R-I_\beta$ has been completed. Thus, although the activation energy of the unimolecular reaction can never be lower than that of the bimolecular reaction, the reaction mechanism can be quite definitely unimolecular and not bimolecular. In such a case the "driving force" of positive ion formation in the unimolecular reaction is greater than the "driving force" of bond formation in the bimolecular reaction.

We may now apply the considerations discussed above to experimental results.

Firstly, in the solvolysis of R – Hal the activation energy of the bimolecular reaction will be high since the reactant group is the solvent molecule (this point is discussed later). When R is Me the activation energy of the unimolecular reaction is much greater than that of the bimolecular reaction, but as R changes from Me to *t*-Bu the activation energy of the unimolecular reaction falls rapidly while that of the bimolecular reaction rises more slowly. Thus we might expect the solvolysis of these halides to change in mechanism along this series from bimolecular S_N2 to unimolecular S_N1 as established by Ingold and co-workers.[4] These authors have studied the effect of OH^- ions on the rate of hydrolysis of R – X as R varies from Me to *t*-Bu, as a method of determining changes in reaction mechanism; their argument being that if OH^- ions do not affect the rate of hydrolysis of a halide it is inconceivable that

the much less basic solvent should function as a reactant in the rate determining process, and hence the hydrolysis reaction of that halide must be of the unimolecular S_N1 type.

The case of the unsymmetrical reaction was discussed in Section (2*c*). It was shown that for the reaction $Y^- + CH_3I$ a change in the nature of Y^- caused a change in the relative energy levels of the CH_3-I extension curve *a*, and the CH_3I^- repulsion curve, *d* (Figure 2). A change in Y^- which caused an increase in the exothermicity of the reaction (that is, caused a drop in the energy level of the final state *f* with respect to the initial state *i*, Figure 2) would cause a drop in the energy level of the $CH_3\ I^-$ repulsion curve *d*, with respect to the CH_3-I extension curve *a*, and this would result in a decrease in activation energy of the reaction. The exothermicity of the reaction $OH^- + CH_3Hal$ has been calculated by Ogg[2c] as about 18 kcal. It is to this exothermicity, which will lower the energy of the transition state, that Ogg attributes the high speed of the reactions of $R-X$ with OH^- ions. The bimolecular reaction with H_2O is not so exothermic as with OH^- ions and so in the energy diagram for the bimolecular reaction with H_2O the $CH_3\ I^-$ repulsion curve will be higher than in the energy diagram for the bimolecular reaction with OH^- ions, and will thus cross the CH_3-I extension curve at a higher energy than in the case of the OH^- reaction. The bimolecular reaction with H_2O will thus have a higher activation energy than the bimolecular reaction with OH^- ions, in accordance with the theorem deduced by Ogg and Polanyi[2c]*.

As R is changed, the exothermicities of the bimolecular reactions of $R-X$ with OH^- ions and with H_2O will not vary much since these reactions are substitutions. If the reactions of $R-X$ with OH^- and with H_2O remain bimolecular in mechanism as R is changed from Me to *t*-Bu we might expect the activation energies of these two reactions to show similar trends for this variation in R. This is not the case however. The effect of OH^- ions on the hydrolysis of RBr as R varies from Me to *t*-Bu has been studied by Bateman, Cooper, Hughes and Ingold[4]. From the rate constants which these authors give it is

* This difference between the reaction of $R-X$ with OH^- ions and with H_2O has been discussed by Ingold and co-workers in terms of the relative basic strengths of the two reactants[4].

seen that the bimolecular reaction rate of RBr with OH^- ions decreases in a way which corresponds to an increase in activation energy of 1·6 kcal. from Me to Et and an increase of 2·4 kcal. from Et to *s*-Pr. On the other hand, if the reaction of R – Br with H_2O is assumed to be bimolecular over this range of R, the variation in rate constant of the reaction H_2O+RBr corresponds to an increase in activation energy of 0·6 kcal. from Me to Et, a decrease of 0·4 kcal. from Et to *s*-Pr, and a decrease of 5·4 kcal. from *s*-Pr to *t*-Bu.

The increase in the bimolecular rate constant on changing from reaction MeBr+H_2O to reaction MeBr+OH^- corresponds to a decrease in the bimolecular activation energy of about 7·5 kcal. In the case of *t*-BuBr it is found that N/10 NaOH has no observable effect on the hydrolysis. If the reaction of *t*-BuBr with H_2O is assumed to be bimolecular, and if the fact that N/10 NaOH has no observable effect on this reaction is taken to mean that the reaction rate of *t*-BuBr with H_2O is at least 50 times more rapid than that with OH^- ions when the concentration of these ions is N/10, then this corresponds to the bimolecular activation energy for the reaction of *t*-BuBr with H_2O being greater than that for the reaction of *t*-BuBr with OH^- by less than 1·4 kcal. This decrease in the difference of activation energy between the reaction of R – X with H_2O and with OH^- ions from 7·5 to less than 1·4 kcal. as R changes from Me to *t*-Bu does not agree with what one would expect if the reaction of R – X with H_2O were bimolecular over the whole range of R.

We may consider, further, the 4,000 fold increase in the rate of reaction of RBr with H_2O as R changes from *s*-Pr to *t*-Bu[4]. If we assume the reaction of RBr with H_2O is bimolecular for this series of R, this increase in rate corresponds to a decrease in activation energy of 5·4 kcal. Since, however, the corresponding decrease in RBr bond strength is only 1·5 kcal.[12], then, even neglecting the increase in steric hindrance which occurs from *s*-Pr to *t*-Bu, we should expect a decrease in activation energy of only about 0·5 kcal. from the bimolecular relationship $\Delta E \approx 0{\cdot}3\Delta D$. (For example, the greater decrease in carbon halogen bond strength of 13 kcal. from ethyl halide to allyl

halide[12] results in an increase in the bimolecular reaction constant of only 38 fold for the bimolecular reaction of the chlorides with iodine ions[3a], in accordance with the relation $\Delta E = \alpha \Delta D$, as discussed in Section (2*d*). Also, the change from *n*-propyl chloride to allyl chloride, which involves a decrease in carbon halogen bond strength of about 11 kcal.[12], causes an increase of only 10 to 100 fold in the rate constants of the bimolecular solvolyses of these halides.[6]) If the increase of steric hindrance from *s*-Pr to *t*-Bu is taken into account we should expect the corresponding decrease in activation energy for the bimolecular reaction of RBr with H_2O to be less even than 0·5 kcal. Thus the increase of 4,000 fold in the rate constant for the reaction of RBr with H_2O as R changes from *s*-Pr to *t*-Bu is not in accordance with what would be expected if the reaction were bimolecular in mechanism over the whole range of R. On the other hand, we have seen in Section (1*f*) that the difference between the ionisation potentials of *s*-Pr and *t*-Bu is able to account for this large difference in rates on the basis of the unimolecular mechanism.

The above discussion suggests that as R changes from Me to *t*-Bu the mechanism of the reaction of R–Br with H_2O changes from bimolecular to unimolecular. If the reaction of *t*-BuBr with H_2O is unimolecular, then using the equations given earlier, the fact that N/10 NaOH has no observable effect on the rate of hydrolysis means that the unimolecular activation energy is higher than the activation energy of the bimolecular reaction with OH^- ions by less than 1·8 kcal. (This again assumes that the unimolecular reaction of *t*-BuBr is at least 50 times more rapid than the reaction of *t*-BuBr with OH^- ions when the concentration of these ions is N/10.) It would thus appear, that as R changes from Me to *t*-Bu, the activation energies of the bimolecular reactions of RBr with OH^- and with H_2O increase, and that the reduction of the activation energy of the unimolecular reaction due to the decrease in the ionisation potential of the radical along this series, brings the activation energy for the unimolecular reaction of *t*-BuBr "below" that for the bimolecular reaction of *t*-BuBr with H_2O and to within less than 1·8 kcal. of the bimolecular activation energy for the reaction of *t*-BuBr with OH^- ions.

Thus, although we have not been able to determine from first principles under what conditions the reaction of R – X will proceed by the unimolecular rather than by the bimolecular mechanism, the discussion presented above gives a quantitative account in terms of a theory of activation energy of the results established by Ingold and co-workers.

Secondly, in the reaction $Cl^- + t$-BuCl, the unimolecular activation energy will be low, the steric hindrance large, and the concentration of Cl^- ions small, so that one might expect from the previous discussion that this reaction could occur by the unimolecular mechanism. This is found to be the case for $Cl^{*-} + t$-BuCl in formic acid solution[39].

Thirdly, we see from our consideration of unimolecular reactions that even though the reaction of R – X is definitely unimolecular, the halide ion X^- which is formed may shield the carbonium ion R^+ so that bond formation between R^+ and reactant would occur more easily on the side away from X^- than on the side toward X^-. Thus one can understand the result which is found experimentally, that even when solvolysis of R – X occurs by the unimolecular mechanism the product is not completely racimised. Ogg and Polanyi[2c] accounted in this way for the fact that inversion accompanies the electrolytic dissociation of an alkyl halide.

(3*f*) *Steric Hindrance in series Ethyl to Neopentyl.*

For the bimolecular reaction of R – Br with sodium ethoxide it is found that the reaction rate decreases along the series Et, *n*-Pr, *i*-Bu, neopentyl[6] (Table I, reaction (8)). The corresponding bond strength changes are known only for the change from Et to *n*-Pr. This change in R causes a decrease in the R – Br bond strength of about 2 kcal[22]. Although we do not know the changes in bond strength associated with the rest of this series, the rate sequence for the reaction of these halides with sodium vapour is Et < *n*-Pr < *i*-Bu (Table I, reaction (11)). An increase in the rate of reaction of R – X with sodium vapour is usually associated with a decrease in R – X bond strength[12]. It thus seems probable that along this series there is a decrease in R – X bond strength, at least from Et to *i*-Bu. Thus this

series of halides resembles the Me to *t*-Bu series in that a decrease in the bimolecular reaction rate with ethoxide ions is associated with a decrease in R – X bond strength and an increase in the rate of reaction with sodium vapour.

As mentioned earlier, Hughes attributes the decrease in the bimolecular reaction rate from Et to *i*-Bu to an increase in electron accession to the reaction centre, although he attributes the small bimolecular constant of the neopentyl halide to steric hindrance. Hughes has discussed the possibility of steric hindrance for the cases when R is *n*-Pr, *i*-Bu and neopentyl in a somewhat similar way to that described in this paper (ref. (6), p. 623). He concludes that in addition to the retarding effect on the bimolecular reaction rate of the electron accession to the reaction centre which operates throughout the series, there is a superposed steric effect, which may in principle enter in all stages of β-substitution, but which assumes real importance only in the case of the neopentyl halide.*

We, however, attribute the decrease of the bimolecular reaction rate along the whole of this series to the increase of steric hindrance, as in the case of the Me to *t*-Bu series.

The change in steric hindrance along the series ethyl to neopentyl has been examined by the same method as that used for the methyl to *t*-butyl series[33]. The transition state configuration of the $CH_2CH_2CH_3$ group is shown in Figure 8. It can be obtained from the transition state configuration of CH_2CH_3 by replacing that β-hydrogen atom which lies in the plane of the central carbon valencies by a methyl group. When the chlorines are placed at distances from the central carbon atom (represented in the figure by a white triangle) equal to those obtained for the transition state of the CH_3Cl reaction, it is found that there is practically no steric interference between the β-methyl group and the chlorines. Most of the steric interference is due to the two β-hydrogen atoms which project out from opposite sides of the central plane. Thus the steric effect of the *n*-Pr group will be little different from that of Et.

The transition state configuration of the neopentyl group is obtained from that of the *n*-Pr group (Figure 8) by replacing by methyl groups each of the two β-hydrogen atoms which

* See footnote on page 4.

project from the central plane. Thus for the neopentyl radical it is a methyl group and not a hydrogen atom which interferes sterically with each halogen in the transition state. When the chlorines are placed at distances from the reacting carbon atom equal to the transition state distance obtained for the CH_3Cl reaction, it is found that there is great steric interference between the chlorines and the projecting methyl groups. The chlorine is interlocked between two of the hydrogens of the methyl group. There is a compression of 0·96A for the chlorine against the methyl carbon atom and a compression of about 0·8A for the chlorine against each of the two methyl hydrogen atoms. To eliminate this methyl chlorine interpenetration the carbon-chlorine bond would have to be bent through an angle of 30°. At this angle of bending, however, a compression of 0·2A occurs between the chlorine and each of the two α-hydrogen atoms.

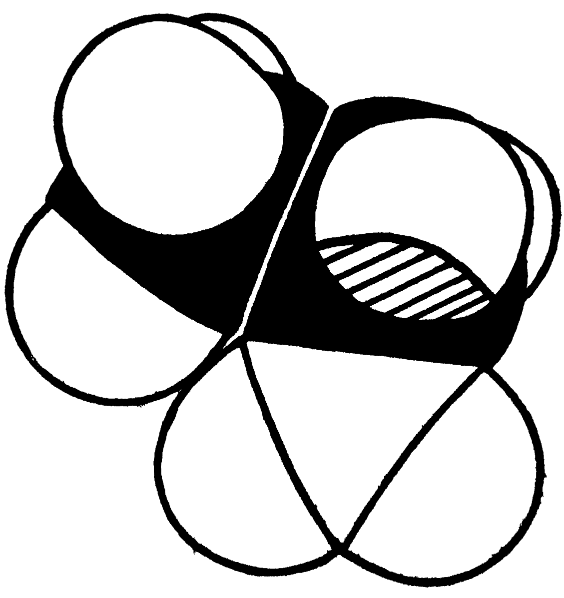


FIGURE 8.

Transition state configuration of *n*-propyl group.

The case of the $CH_2CH(CH_3)_2$ group is anomalous. In the symmetrical transition state configuration for this group the single β-hydrogen atom lies in the plane of the reacting carbon valencies, and the two β-methyl groups project out from this plane, one on each side. This configuration would cause practically the same steric hindrance as the neopentyl group since the additional β-methyl group of neopentyl lies in the plane of the central carbon valencies and has little steric effect. The steric effect may be reduced below that of neopentyl by the use of unsymmetrical transition state configurations. For example, if one of the β-methyl groups is placed in the plane of the reacting carbon valencies, then projecting out of this plane is a β-hydrogen atom on one side and the other β-methyl group on the other side. This structure will behave like a *s*-propyl group towards one chlorine and like a neopentyl group towards the other chlorine.

The configuration of the $CH_2CH(CH_3)_2$ group which has least steric hindrance is probably that in which both β-methyl groups project symmetrically from the same side of the plane containing the reacting carbon valencies, while the β-hydrogen atom projects directly from the other side of this plane. For this transition state configuration one chlorine is compressed against the two β-methyl groups. There is a compression of 0·45A against a hydrogen atom and 0·49A against a carbon atom for each of these methyl groups. The other chlorine is compressed against the β-hydrogen atom to the extent of 0·68A.

The results for this series using iodine as the halogen show compressions that are about 0·2A greater than those obtained for chlorine.

From this discussion we should expect the steric hindrance of the bimolecular reaction to increase along the series from ethyl to neopentyl. In this series we should expect to find the smallest increase in steric hindrance in the change from ethyl to *n*-propyl. We should thus expect the bimolecular reaction rate of these halides to decrease markedly along this series, and to show the least decrease in the change from ethyl to *n*-propyl. This is found to be the case (Table I, reactions 4 and 8).

Bartlett and Rosen[7] have also discussed the steric hindrance present in the reactions of neopentyl halides. These authors have studied the bimolecular rates of iodine substitution for the bromides R – Br. They suggest that if the effect of the $(CH_3)_3C$ group in neopentyl halide is "chemical," then this effect should be partially transmitted through unsaturated linkages interposed between the group and the reacting carbon centre. If, however, the effect is steric then this removal of the group further from the reacting centre should cause the group to have no effect at all. The two compounds (*a*) $(CH_3)_3C\ C{\equiv}CCH_2Br$ and (*b*) $CH_3CH_2CH_2CH_2C{\equiv}C\ CH_2Br$ should be different as regards bimolecular reaction rate if the effect of the $(CH_3)_3C$ group in neopentyl halide is chemical, but should show no difference if the effect of the $(CH_3)_3C$ group in neopentyl halide is steric. Bartlett and Rosen found that these compounds react with iodine ions some 20,000 times as fast as does neopentyl bromide, and there is no hindrance in compound (*a*) compared with compound (*b*). Actually (*a*) reacts slightly faster than (*b*). These authors conclude that the hindrance to the negative ion reactions of neopentyl halides cannot be "chemical" in nature, but must be steric.

There is a definite decrease in bimolecular reaction rate from *n*-Amyl to *i*-Amyl (Table I, reactions 1 and 4). The transition state configuration of the *i*-Amyl group will be obtained from that of the *n*-Pr group (Figure 8), by replacing the two γ-hydrogens which project from the central plane by methyl groups. The steric effect of these two methyl groups projecting, one from each side of the central plane, will be greater than the steric effect caused by replacing one γ-hydrogen of *n*-Pr by an ethyl group to give *n*-Am (or by a methyl group to give *n*-Bu), which, by rotation of the γ-carbon atom around the $\beta-\gamma$ bond, can be brought into the central plane and away from the halogens. The introduction of a methyl group into *n*-butyl halide to give *i*-amyl halide has a similar effect on the bimolecular reaction rate as has the introduction of a methyl group into ethyl halide to give *n*-propyl halide (Table I). We find that the γ-carbon-iodine distance in the transition state configuration of the $I^- + n\text{-}Pr - I$ reaction is practically the same as that of the δ-carbon-iodine distance in the transition state

configuration of the $I^- + i$-Am-I reaction. This supports the suggestion that the effect of methyl substitution in decreasing the bimolecular rate constant is steric in nature.

(3*g*) *Absence of Steric Hindrance in Series Ethyl to Allyl to Benzyl.*

The transition state configurations for allyl and benzyl which were referred to earlier (Section 2*d*) are shown in Figures 9 and 10. The black areas represent the double-bonded carbon atoms. The reacting carbon atom, which has been left white, has its three valencies co-planar. All the other atoms lie in this plane too, and because of this they will cause little steric hindrance. Thus the change from ethyl to allyl or ethyl to benzyl which has been discussed previously, although involving an increase in the size of the group linked to the reacting carbon atom, will not involve an increase in steric hindrance.

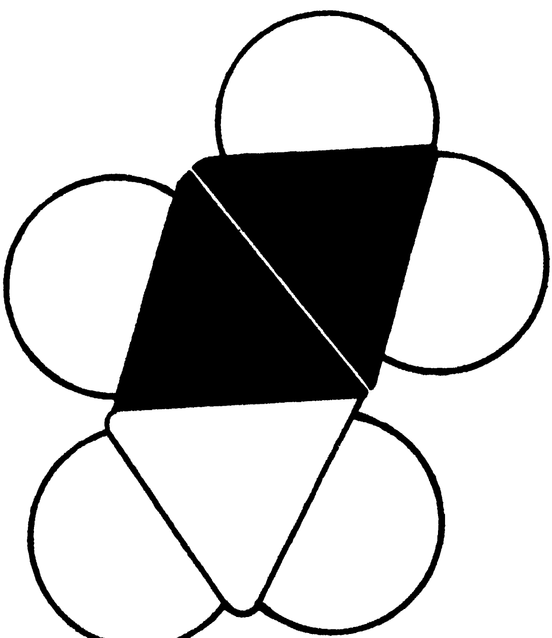


FIGURE 9.
Transition state configuration of allyl group.

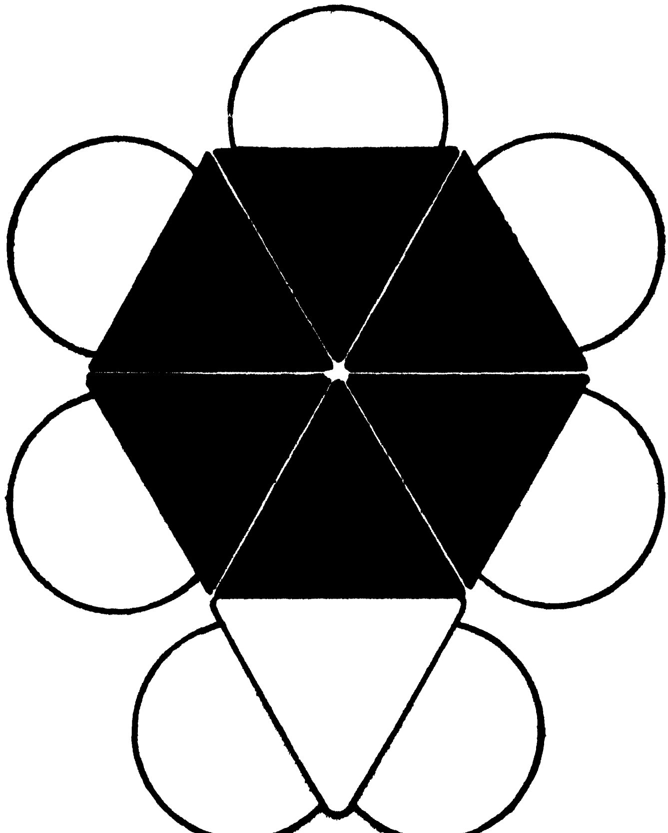


FIGURE 10.
Transition state configuration of benzyl group.

(4) BIMOLECULAR REACTIONS INVOLVING ADDITIONAL RESONANCE ENERGY IN THE TRANSITION STATE.

So far we have considered the effect of changes in the nature of R upon the following factors: (*a*) R – X bond strength, (*b*) ionisation potential of R, (*c*) heat of solution of R^+, (*d*) steric hindrance of the bimolecular reaction. Factors (*a*), (*b*) and (*c*) are concerned in the unimolecular reaction of R – X. Factors (*a*) and (*d*) are concerned in the bimolecular reaction of R – X.

There is a further factor which is involved only in the bimolecular reaction. A change in the nature of R may increase the resonance energy of the transition state for the bimolecular reaction by providing alternative positions for the accommodation of the negative charge of the attacking ion[40]. Such an increase in the resonance energy of the bimolecular transition state would tend to reduce the activation energy of the bimolecular reaction. M. G. Evans and Polanyi[40] suggest that this is the reason why a negative group in the halide molecule may have an accelerating effect on the bimolecular reaction of the halide with negative ions.

If a change in R increases the R – X bond strength and at the same time increases the resonance energy of the bimolecular transition state, the resulting change in the activation energy of the bimolecular reaction will be determined by the relative importance of these two effects.

The occurrence of an increase in the resonance energy of the bimolecular transition state for the reaction of organic halides with sodium vapour has also been discussed along similar lines[40,11].

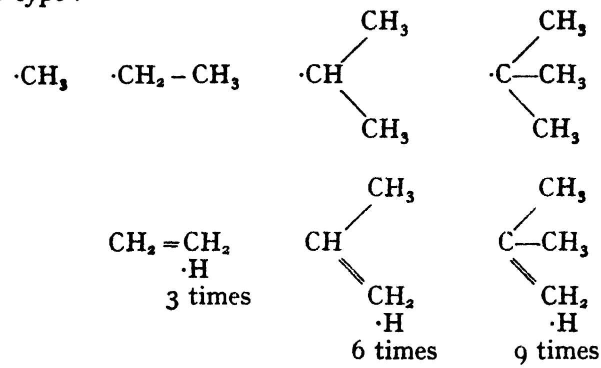
(5) Discussion.

(5*a*) *Unimolecular Reactions.*

To predict the effect of a change in R on the rate of the unimolecular reaction of R – X one requires a knowledge of the accompanying changes in the three factors (1) bond strength of R – X, (2) ionisation potential of the radical R, and (3) heat of solution of the positive ion R^+.

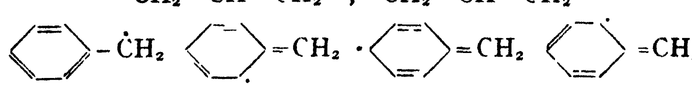
(1) A change in R which involves an increase in the resonance energy of the radical R will tend to reduce the bond strength of R – X since it decreases the energy of the dissociated state R+X. The relationship between the change in the resonance energy of the radical R and the resulting change in the bond strength of R – X has been discussed for the series of R, CH_3

to $C(CH_3)_3$ by Baughan, M. G. Evans and Polanyi[13]. The observed decrease in R – I bond strength as R changes from CH_3 to $C(CH_3)_3$[12] has been attributed by these authors to the increase in resonance possibilities along this series of radicals of the type :



The low R – I bond strength when R is benzyl or allyl has been attributed to the following possibilities of resonance in the radicals[12] :

$$CH_2=CH-\dot{C}H_2 \quad , \quad \dot{C}H_2-CH=CH_2$$



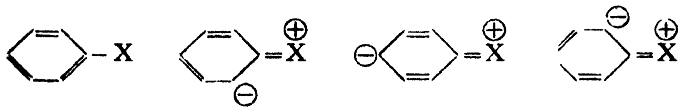
If a change in R involves an increase in the resonance energy of the undissociated molecule R – X, the energy of the undissociated state is thereby lowered and (if there is no corresponding change in the resonance energy of the radical R) this tends to increase the bond strength of R – X. This type of resonance occurs in the vinyl halides

$$CH_2=CH-X \qquad \overset{\ominus}{C}H_2-CH=\overset{\oplus}{X}$$

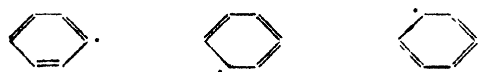
and it is to the resulting decrease in the energy of the undissociated molecule that the increase in carbon-iodine bond strength from methyl iodide to vinyl iodide has been attributed[12].

A change in R may involve an increase in the resonance energy both of the undissociated molecule and of the radical, and these two effects will oppose each other. An example of

this kind occurs in chloro-benzene. Here the undissociated molecule may resonate thus :



and the free radical may resonate thus :



It is found that the carbon iodine bond strength of iodobenzene is the same as that of methyl iodide, showing that in iodobenzene these two effects tend to cancel out[12].

(2) The relationship between a change in the nature of the radical R and the resulting change in the ionisation potential of R is not clearly understood. The ionisation potential of the methyl radical is 10·07 e.v.[14] We may write this :

$$CH_3 \longrightarrow CH_3^+ + \epsilon - 10{\cdot}07 \text{ e.v.}$$

When a hydrogen atom of the methyl radical is replaced by a second methyl group, the resulting ethyl radical has the following resonance possibilities[13] :

$$\cdot CH_2 - CH_3 \qquad \underset{\substack{H \\ 3 \text{ times.}}}{CH_2 = CH_2}$$

This resonance, involving the free valency electron of the radical, will tend to make the ionisation potential of the ethyl radical greater than that of the methyl radical. The ethyl positive ion, however, will have resonance possibilities similar to those of the ethyl radical :

$$^+CH_2 - CH_3 \qquad \underset{\substack{H^+ \\ 3 \text{ times}}}{CH_2 = CH_2}$$

and this resonance, involving the positive charge of the ion, will tend to lower the ionisation potential of the ethyl radical below that of methyl. If the resonance energies of the radical and of the positive ion are the same, the ionisation potential of the ethyl radical will be the same as that of the methyl radical. If the resonance energy of the positive ion is greater

than that of the radical the ionisation potential of the ethyl radical will be less than that of methyl, and vice versa.

The observed decrease in ionisation potential from methyl to ethyl[14] (see Section (1*c*)), shows that the increase in resonance energy of the radical R from CH_3 to C_2H_5 (resulting in a decrease of R – X bond strength) is accompanied by a greater increase in the resonance energy of the ion R^+ from CH_3^+ to $C_2H_5^+$. Further, the decrease in ionisation potential along the series of radicals from CH_3 to $C(CH_3)_3$ (Section (1*c*)), shows that as the resonance energy of the radical R increases along this series (resulting in a decrease in R – X bond strength), not only does the resonance energy of the ion R^+ increase, but the difference in resonance energy between R^+ and R increases. This suggests that the energies of the states ${}^{+}CH_2-CH_3$ and $CH_2{=}\underset{H^+}{CH_2}$, for example, lie closer together than do the energies of the states $\dot{C}H_2-CH_3$ and $CH_2{=}\underset{\cdot H}{CH_2}$. It was suggested by Baughan, M. G. Evans and Polanyi[13] that in the positive ion, resonance states such as $CH_2{=}\underset{{}^{+}H}{CH_2}$ will not have an excessively high energy, because although the ionisation potential of the hydrogen atom is large, the small radius of the proton involves small repulsive energies. Because of this these authors expect comparable resonance energy in the radicals and the positive ions. The results of electron impact experiments, however, show that the resonance energy of the positive ion is much greater than that of the corresponding radical for the series CH_3 to $C(CH_3)_3$. It would seem, then, that the small repulsive energies involved in the resonance states involving protons enable these states to contribute more effectively to the resonance energy of the positive ion than the states containing hydrogen atoms contribute to the resonance energy of the radical.

Thus if we introduce a methyl group into the radical R in such a position that resonance of the type discussed above is possible, we should expect the resulting decrease in the bond strength of R – X to be accompanied by a decrease in the ionisation potential of R.

The ionisation potential of the phenyl radical has been calculated as 10 5 e v from electron impact experiments using the value of 4 0 e v for the energy of dissociation of the Ph – H bond[41]

Stevenson[20] gives a value of 9 9 e v for the ionisation potential of the vinyl radical This is close to the value given for methyl The increase in R – X bond strength which occurs when R changes from methyl to vinyl is due to resonance in the undissociated molecule This resonance cannot occur in the vinyl radical or positive ion and so the ionisation potential of vinyl might be expected to be of the same order as that of methyl

(3) The relationship between a change in the nature of R and the resulting change in the heat of solution of the positive ion R^+ has been discussed earlier for changes caused by the introduction into R of neutral methyl groups It was found that when a methyl group is introduced into R the heat of solution of the positive ion decreases

We have discussed the unimolecular reactions of R – X for the series of R from CH_3 to $C(CH_3)_3$ in an earlier section (1*f*) The discussion of other series of halides is not possible as yet because the factors involved cannot be estimated

Since, however, for the vinyl and phenyl halides the ionisation potentials of the radicals (given above) are as high as that of methyl, the carbon halogen bond strengths are similar to that of methyl halide[12], and the heats of solution of the R^+ ion will be, if anything, less than that of Me^+, we might expect the unimolecular reactions of vinyl and phenyl halides to resemble the unimolecular reaction of methyl halide and to be extremely slow

It follows from the above discussion that the introduction of a methyl group into the radical R causes a decrease in the heat of solution of the positive ion R^+, and this tends to reduce the unimolecular reaction rate of R – X It also follows that if the introduction of a methyl group into R causes a reduction in the R – X bond strength, we should expect an accompanying decrease in the ionisation potential of R, and both these effects will tend to increase the unimolecular reaction rate of R – X Thus, if the introduction of a methyl group into R results in

an increase in the unimolecular reaction rate of R – X, it may be concluded that this change in R is accompanied by a decrease in the R – X bond strength. The converse of this, of course, does not necessarily hold. This conclusion is utilised later in the discussion of bimolecular reaction rates.

(5*b*) *Bimolecular Reactions.*

According to the Polanyi theory a decrease in the R – X bond strength ΔD should lead to a decrease in the activation energy ΔE of the bimolecular reaction of R – X, and the relationship between these two terms should be $\Delta E \approx 0{\cdot}3\ \Delta D$. This applies to the change of R from ethyl to allyl or benzyl but not to the change of R from CH_3 to $C(CH_3)_3$. The fact that the decrease in R – X bond strength as R changes from CH_3 to $C(CH_3)_3$[12] is accompanied by a decrease in the bimolecular reaction rate of R – X is attributed to the increase in steric hindrance along this series which more than outbalances the effect due to the decrease in R – X bond strength.

To test this theory we may consider examples in which the introduction of a methyl group into R cannot cause steric hindrance in the bimolecular reaction. If, in the absence of steric hindrance, the introduction of the methyl group causes a decrease in the R – X bond strength we should expect an increase in the bimolecular reaction rate. The direction of the change in the R – X bond strength due to methyl substitution may be found from the change in the corresponding unimolecular reaction rate. As discussed previously (Section (5*a*)) if the introduction of a methyl group into R causes an increase in the rate of the unimolecular reaction of R – X, we may conclude that the introduction of the methyl group produces a decrease in the R – X bond strength. Thus, in the absence of steric hindrance, if the introduction of a methyl group into R causes an increase in the unimolecular reaction rate of R – X, we should expect, on the Polanyi theory, that the bimolecular reaction rate of R – X would also increase.

Example (1). The unimolecular and bimolecular reactions of substituted allyl chlorides have been discussed by Hughes (ref. (6), p. 628). The rate of solvolysis of γ-methyl allyl

chloride in 50 % aqueous ethyl alcohol is found to be greater than that of allyl chloride. The solvolysis of γ-methyl allyl chloride in this solvent is substantially unimolecular. The solvolysis of allyl chloride is bimolecular, the solvent molecule acting as a reactant. The unobserved unimolecular rate for allyl chloride, however, will be less than the observed bimolecular rate and so the rate sequence for the unimolecular reactions will be γ-methyl allyl $>$ allyl.

This rate sequence would indicate that the introduction of a methyl group into the γ-position of allyl chloride causes a decrease in the R Cl bond strength, due, probably, to the three additional resonance forms possible in the γ-methyl allyl radical of the type :

$$CH_3\ \ CH\ \ CH-\dot{C}H_2 \qquad \underset{\cdot H}{C}H_2=CH-CH=CH_2$$

3 times.

On the Hughes and Ingold theory, this rate sequence indicates that the electron releasing capacity of the methyl is transmitted to the reactive carbon centre. Hughes considers the effect of the methyl group to be transmitted with undiminished power to the seat of substitution thus :

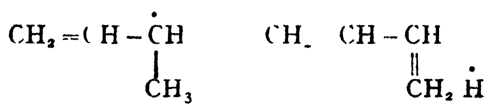
$$CH_3 \rightarrow CH=CH-CH_2-Cl.$$

Since the introduction of the methyl group in the γ-position of the allyl group will have no effect on the steric hindrance of the bimolecular reaction of R – Cl we should expect on the Polanyi theory that the bimolecular rate sequence would be the same as the unimolecular rate sequence: γ – methyl allyl $>$ allyl.

For reaction with OEt^- ions the observed bimolecular rate sequence is γ-methyl allyl $>$ allyl. This sequence is in agreement with the Polanyi theory.

Example **(2). In contrast to Example (1) we may consider the case of α-methyl allyl chloride (ref. 6, p. 628). The unimolecular reaction rate of this halide is of the same order as that of γ-methyl allyl chloride, the unimolecular rate sequence of the three halides being γ-methyl allyl $\sim$ α-methyl allyl $>$ allyl. This increase in unimolecular reaction rate when a methyl group**

is introduced into the α-position of allyl chloride again indicates a decrease in the R – Cl bond strength due, probably, to the three additional resonance forms possible in the α-methyl allyl radical of the type :



3 times

On the Hughes and Ingold theory, the unimolecular reaction rate of α-methyl allyl chloride is greater than that of allyl chloride because of the increased electron accession to the reaction centre in the former compound due to the α-methyl group. The equivalence of the unimolecular reaction rates of γ-methyl allyl chloride and α-methyl allyl chloride justifies Hughes' assumption that the electron releasing capacity of the γ-methyl group is transmitted with undiminished power to the seat of substitution.

Thus on the Hughes and Ingold theory one might expect the α- and γ-methyl allyl chlorides to behave similarly in their bimolecular reactions.* On the Polanyi theory, on the other hand, because the α-methyl group will cause steric hindrance in the bimolecular reaction, one would expect the bimolecular rate constant of α-methyl allyl chloride to be less than that of γ-methyl allyl chloride. Further, by analogy with the effect of steric hindrance in the change from methyl chloride to ethyl chloride, one would also expect the bimolecular rate constant of α-methyl allyl chloride to be less than that of allyl chloride. The observed bimolecular rate sequence is found to be γ-methyl allyl > allyl > α-methyl allyl. This sequence is in agreement with the Polanyi theory.

Rate sequences similar to those described by Hughes have been obtained for the unimolecular and bimolecular reactions of γ-methyl allyl chloride and α-methyl allyl chloride by Young and Andrews[42]. These results show that at 25° C. the ratio of the bimolecular rate constants for γ-methyl allyl chloride / α-methyl allyl chloride is 55 / 1. At the same temperature, however, allowing for the partial bimolecular character of the

* See, however, footnote on page 4.

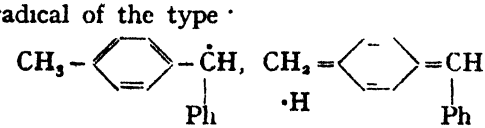
hydrolysis of γ-methyl allyl chloride, we estimate from these authors' results that the ratio of the unimolecular rate constants for γ-methyl allyl chloride/α-methyl allyl chloride is not less than 1/2. The marked difference between the rate sequences of the unimolecular and bimolecular reactions is to be expected if steric hindrance is present in the bimolecular reaction of α-methyl allyl chloride but not in the bimolecular reaction of γ-methyl allyl chloride This is a strong argument for the assumption that the observed bimolecular rate sequence, γ-methyl allyl > α-methyl allyl is determined by steric hindrance

In the reactions of the substituted allyl chlorides considered above there is the possibility that the bimolecular reactions involve attack by the nucleophilic reagent at the γ-carbon atom and not at the α-carbon atom Hughes describes experiments which show that for the α-methyl allyl chloride and the γ-methyl allyl chloride the bimolecular reaction involves attack at the α-carbon atom (ref 6, p 630)

The experiments of Roberts, Young and Winstein[43] also show that the bimolecular replacement of the chloride group by OEt^- ions in α- and γ-methyl allyl chlorides occurs without allylic rearrangement

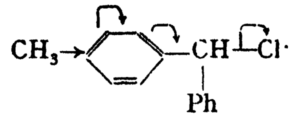
Example (3) In the previous examples the presence of the double bond in the allyl group enables a methyl group in the γ position to contribute to the weakening of the $R-X$ bond (or to the electron accession to the reaction centre), as effectively as if it were in the α-position, although it is far enough removed from the reaction centre to have no steric effect on the bimolecular reaction

A similar condition obtains by using the benzene group in place of the allyl double bond It is found that for the hydrolysis of $p-x-C_6H_4CHPhCl$ the unimolecular rate sequence is $p-CH_3C_6H_4CHPhCl > H\ C_6H_4CHPhCl$[44] This increase in unimolecular reaction rate, caused by the introduction of a methyl group, indicates that the $R-Cl$ bond strength has been reduced, due, probably, to the increase in resonance possibilities in the radical of the type ·



3 times.

On the Hughes and Ingold theory the increase in unimolecular reaction rate will be attributed to the electron releasing capacity of the methyl group transmitted to the seat of reaction through the benzene group thus :



Since the introduction of the methyl group in the para position of the benzene group will have no effect on the steric hindrance of the bimolecular reaction of R – X, we should expect on the Polanyi theory that the bimolecular rate sequence would be the same as the unimolecular rate sequence :

$$p.CH_3C_6H_4CHPhCl > H.C_6H_4CHPhCl.$$

The bimolecular rate sequence is not known for these compounds. We may, however, compare these unimolecular rates with the bimolecular rates for the reaction of $p.x.C_6H_4CH_2Br$ with C_5H_5N. The corresponding bimolecular rate sequence here is $p.CH_3.C_6H_4CH_2Br > HC_6H_4CH_2Br$[45]. This sequence is in agreement with the Polanyi theory.

(5*c*) *Bimolecular Reactions of Vinyl and Phenyl Halides.*

The carbon-iodine bond strengths of methyl and phenyl iodides have been found to be about the same[12], and consideration of bond strength alone would lead one to expect similar bimolecular rate constants for methyl and phenyl halides. The rates of reaction of these halides with sodium vapour are found to be similar (Table I, reaction (11)), but in solution the bimolecular reaction rates of phenyl halides are much less than those of methyl halides. Fairbrother and Warhurst[10] have suggested that the slow bimolecular reaction rate of phenyl chloride in solution is due to the steric hindrance of the benzene group. The benzene group will not cause steric hindrance in the reaction with sodium vapour where the attack is at the halogen atom (as in the " positive mechanism "). In the negative ion reaction, however, where the attack is at the reactive carbon centre (" negative mechanism ") the presence of the benzene group will cause the attacking ion to approach

the reactive carbon centre from the same side as that occupied by the halogen atom. The bimolecular reaction rates of the phenyl halides will thus be smaller than those of the methyl halides because of this steric hindrance.

The bimolecular rate constants of vinyl halides are also slow. The carbon-iodine bond strength of vinyl iodide, however, is only 1 kcal. greater than that of methyl iodide[12], and the rate of reaction of vinyl chloride with sodium vapour is only slightly less than that of methyl chloride (Table I, reaction (11)). In vinyl halide the valencies of the reactive carbon atom are not tetrahedral, and it is not known what the transition state configuration for the bimolecular reaction will be in such a case. It is thus difficult to assess the steric hindrance for the bimolecular reaction of vinyl halide.

SUMMARY.

The unimolecular reactions of the organic halide R – X have been discussed in terms of recent data on (*a*) bond strength of R – X, (*b*) ionisation potential of radical R, and (*c*) heat of solution of ion R^+.

The bimolecular reactions of organic halides have been considered in terms of (*a*) bond strength of R – X, (*d*) steric hindrance, and (*e*) resonance energy in the transition state. Calculations of steric hindrance for the series of radicals, Me, Et, *s*-Pr, *t*-Bu and Et, *n*-Pr, *i*-Bu, neopentyl, have been described, and an attempt has been made to estimate the effect of steric hindrance on the activation energy of the bimolecular reaction. It is concluded that the decrease in the bimolecular reaction rate of R – X along the series of R, Me to *t*-Bu and Et to neopentyl is due to the increase in steric hindrance along these series.

The conditions which determine the mechanism of reaction have also been discussed and the typical change of mechanism from bimolecular S_N2 to unimolecular S_N1 established by Ingold and co-workers has been interpreted in terms of a theory of activation energy.

The author wishes to express his best thanks to Professor M. Polanyi for much helpful advice and encouragement.

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The Climate of Lancashire.

By Gordon Manley, M.A., M.Sc.
President, Royal Meteorological Society, 1945–6.

Three hundred years ago Lancashire was a remote and thinly populated land of undrained mosses, damp pasture, wooded inland valleys and windswept coastal marshes. It was then a land of independence of mind ; of inquiring temperament ; of fair maids. As far as one can judge it has always been a land in which the opportunist individualism of this cross-bred population of ours was likely to be rather more marked than elsewhere, a result which may perhaps be attributed to marginal position from the geographical standpoint and also from that of climate.

It is a land in which you will still find men of vision with a well-developed capacity for abstract reasoning and its later application to practical ends. Such attitudes of mind, however, are widespread in the neighbouring counties. It is noteworthy how well developed is that spirit of enquiry which produces our great mathematical physicists, of whom so many come of Northern English stock. Henry, your own President, remarked on this in 1854. The same spirit, varied a little in its development, made the great inventors and engineers of the age which built Manchester and gave birth to this Society. I will only remind you here of five names : Jeremiah Horrocks, John Dalton, Joseph Whitworth, Arthur Eddington and James Chadwick. Accuracy of observation and measurement is akin to the straightness of aim of the fifteenth-century Lancashire bowmen. The glorious rhythm and accuracy of pitch of a fine Northern choir betokens the same attitude of mind, in which the Celtic regard for melody is couched in the firm grasp of the Scandinavian sense of time and space.

Moreover, the observation of natural phenomena is enforced. Those who come up the railway from London will recall how often they feel the strengthened vigour of the west wind beyond Wigan. Lancashire can never forget the sea ; witness the bending ash trees on the hillside.

Looking inland, however, as Leland did in 1538, they see the long line of the hills ; to this day the Lancashire man of the cotton towns goes for succour to his moors. It is no wonder that between the sea and hills the men of North-West England rank high among those who have developed the observational sciences appertaining to the earth's surface.

But we must not forget that the same elements went to make Westmorland and Cumberland. Collingwood gave us in 1896 (" Thorstein of the Mere ") that delightfully expressive saga of the times when Scandinavian pioneers, indigenous Celts and more recent Anglian settlers intermingled in Furness a thousand years ago. Conscious regard for the weather, coupled with the desire to count and measure, has produced in all three counties a remarkable number of observant pioneers in the study of meteorology. Now you can see the reasons for this introduction. Why did N.W. England produce so many early observers and users of instruments ?

Lancashire produced that most enterprising man, Richard Towneley—that seventeenth-century squire from near Burnley who devised his own raingauge. Far from the little group of early scientists who were then beginning to meet in London in the newly founded Royal Society, he pursued his investigations and left us one of the earliest records of rainfall in the world, between 1677 and 1704. Cumberland, however, was the birthplace of Dalton, who began his instrumental records at Kendal in 1787. As one example of many other men less well known who have played their part we may name Joseph Atkinson of Carlisle, who in 1840 produced the first rainfall map. It is the glory of this Society to have had many of these early scientists among its members, and to have published in the Memoirs summaries of their work of the greatest value, and deductions not uncommonly foreshadowing later developments. Campbell's views in 1793 on the character of the air reaching Lancaster are not remote from our modern concept of air-masses ; Sturgeon at Kirkby Lonsdale in 1848 observed the cloud characteristic of standing waves in the surface air stream, ninety years before the German glider pilots began to notice and make use of them.

Yet while these early deductions are interesting, we are far beyond them. But the observations remain ; and hitherto no one has tried to put together these old observations in such a way as to make a complete picture of the vicissitudes of the Lancashire climate since instrumental recording began. Two years ago, in connexion with other work, I resolved to attack the problem presented by the early temperature observations, as I found that there was, in Lancashire and the adjacent counties, a sufficient body of material to be able to build up the story for

a longer period than elsewhere. The results have recently been presented in some detail to the Royal Meteorological Society (Q. J. Roy. Met. S., January, 1946). But it is appropriate that I should also present them here in recognition of the assiduous work of so many of your early members, although I will abridge the more technical details of the methods by which such a reduction of the early data has been effected. It does give me great pleasure to say that I believe I have succeeded as far as is now possible in the reduction to modern standards of the records so splendidly maintained by your great President, John Dalton. In addition, I have to thank the Society for the opportunity to use the charred notebooks of his brother's hitherto unreduced records at Kendal which were saved after the German raids. The reduction might have been better done if the MS. of the Manchester record had also survived ; as it is, some uncertainty remains. It may be asked, why was a reduction to modern standards not attempted at an earlier date ; the answer is that it was found to be too difficult, and I have only been able to tackle the problem myself in the light of more recent knowledge.

Many early observations were collected, summarised and published in the Memoirs by Garnett, in 1793 and 1796. In addition, I have made use of the later papers by Dalton, Blackwell, Holt, Curtis, Vernon, Roberts, Casartelli and Mackereth among your own past members. To these may be added men such as Miller of Whitehaven, who was the first to initiate the study of the rainfall of the Lake District mountains in 1845. He established the celebrated Seathwaite raingauge, where a record has now been continuously kept for a hundred years. Marshall of Kendal kept a splendid rainfall record, and also a temperature record from 1823 to 1860 ; he was one of the original members of the Royal Meteorological Society. Barnes, one of a long series of celebrated Carlisle medical men, published (1830) the results of earlier observations at that town kept by Pitt.

To go back to the more shadowy eighteenth century, I have examined the 25 years of manuscript records kept by Hutchinson at Liverpool (1768—1793), through the courtesy of the authorities of the Picton Library. At the Royal Society in London an MS. summary exists of Vernon's record from Middlewich in Cheshire (1768—1774) ; Dobson of Liverpool summarised four years of observations in the Philosophical Transactions for 1778.

Holt of Walton published monthly summaries (1795—1801) in the *Gentleman's Magazine;* he was the versatile man who completed the first survey of the agriculture of Lancashire, with that delightful preamble about "the beauty of the Lancashire witches, only matched by the martial prowess of her men". And farther back, another Carlisle doctor (Smith) gave us records in the *Gentleman's Magazine* from 1756—1759. Finally, a fragmentary MS. summary by a Bolton doctor (Rogers) in the Royal Society's Library covers part of 1753—1754, and is the earliest temperature record I have found for any part of North-West England. Detailed references are given for all these sources in my paper to the Royal Meteorological Society. From 1847 onward numerous Lancashire records are available; some of which, like Stonyhurst, have been maintained down to the present day.

It will be seen that no complete series of observations is available for any one location. Accordingly, some time was spent on a preliminary investigation, to see whether the values of monthly mean temperature taken in different parts of Lancashire, Westmorland and Cumberland could be amalgamated. It became evident that from 1784 onwards there were always at least two stations available generally to the north and to the south—for example, Manchester and Kendal. On examination, using the modern stations, it was evidently possible to derive from the mean of two or more stations, situated on or close to the plain, a value which approximated very closely to the mean temperature for stations in the plain in the neighbourhood of Preston, the plain being assumed to be 50 feet above sea level. It was also justifiable to incorporate the records from the more distant Cumberland plain, which obviously undergoes very much the same climatic vicissitudes as that of Lancashire from month to month; especially when they were "balanced" by data from the southern end of Lancashire.

But there is a much more serious problem to be faced by all who would endeavour to bring old observations to modern standards, namely the difficulty of exposure. Since about 1880 it has been standard practice to use Stevenson screens. Before this, some stations (Stonyhurst, Bidston and Liverpool Observatories) used old-fashioned types of screen attached to north walls, at various heights above the ground. At others, thermometers were hung on "Glaisher stands", on which maxima are

generally too high as the thermometers are imperfectly sheltered from radiation. Before 1850 it was a frequent practice to hang thermometers on a shaded "north wall", and before 1830 readings at fixed hours were commonly made, self-registering thermometers being little used. (Blackwell was one of the first Lancashire men to use them, at Crumpsall, 1821—1828.) Further, the majority of early thermometers, especially before 1800, were liable to appreciable error which was not always allowed for.

It is necessary, therefore, to devise for each type of station a method of approximating the original values of the monthly mean temperature to those which would be given in a Stevenson screen under modern conditions. This is a very long job, but the technique is fairly established, and I will spare this Society the arguments except with regard to Dalton.

The Reduction of Dalton's Observations.

At Kendal Dalton kept his thermometer between 18 in. and 2 ft. above the ground in the shade of what he called "a large gooseberry tree"; the "tree" or bush was in the shade of the adjacent house for a great part of the year. Had maxima and minima alone been recorded it is doubtful whether such an exposure would have been valuable at all. Readings, however, were made at fixed hours thrice daily, and the MS. record was continued with great care by Dalton's brother, after the better-known Dalton had come to Manchester. A careful consideration of the descriptions available and of the temperatures given, in the light of modern knowledge, led me to conclude that the mean shade temperature derived from fixed hour observations and suitably corrected was closely comparable with that in a modern screen, apart from possible thermometer errors. Moreover, Gough, the blind scientist of Kendal, who was also an early contributor to this Society, kept a record nearby which gives something of a check.

At Manchester we have the evidence that from 1804—1830 Dalton hung his thermometer outside a first-floor bedroom window in George Street. It was shaded by means of a board from direct sunshine, but was adjacent to, though separate from, a wall facing ESE.; and he read it thrice daily with the utmost regularity. Indeed, his scientific life may be said to have begun and ended with meteorological observations, and the effort made

by him in the keeping of 57 years of records should not go unrecognised by posterity.

But the problem remained: what was the appropriate correction to apply to Dalton's recordings to make them representative of the "Lancashire plain"? We all know that "urban" average temperatures are distinctly higher than those of the adjacent country, and Dalton's records were kept in a built-up area in a town which nearly trebled its population during his period of residence. The loss of Dalton's MS. made it impossible to investigate the extent of the radiation effects in his built-up surroundings. We have, however, in recent years a series of Manchester records, one of which has been kept in an enclosed yard by Oldham Road, and another adjacent to this building at the Godlee Observatory. Others at Whitworth Park and in the country, e.g. at Barton, give the opportunity of estimating the correction, month by month, to be applied to means of temperature kept in the city in order to bring them to "country" standards.

As Dalton's rather narrow street could be considered as a half-enclosed, built-up area, I applied corrections to his means of temperature equal to half those applicable at the modern station, Oldham Road. I had already concluded that Dalton's readings gave a fair index of the air temperature in the street, just as those at Oldham Road or Godlee Observatory give the air temperature in a yard or garden subject to radiation from the surrounding buildings. This method of adjustment is apparently rather rough and ready, but the results fell very well into step with those derived from country stations such as Crumpsall, which was then well outside the city.

Nevertheless, that only answered for George Street. During the earlier years when he was resident at the College the values are less trustworthy, perhaps on account of his propensity for making his own thermometers at that time. The exposure of the instruments cannot be determined; fragmentary evidence suggests the shade of a north wall overlooking the garden. Then from 1830 onward (in Faulkner Street) the trend of his values month by month is good, but the corrections to bring them to "country" standards are obviously larger than they were in George Street. Dalton himself suspected that his later values were not strictly comparable with those of his middle period in

George Street, but he made no detailed investigation of the reasons as far as we know. Accordingly, his values from 1794—1803 and from 1830—1840 must be treated with reserve, while the last years (1841 to his death in 1844) have been lost. In the tables I have constructed below the values for these periods have been largely derived by using other Lancashire or Westmorland records. (Walton from 1795—1801, Kendal from 1823—1860 are most useful; in addition, there are other stations with which the Manchester data can be confirmed or supplemented, including a very good record from Carlisle (1801—1824), using fixed-hour readings.)

The rival city of Liverpool had also its meteorological observers. Since 1845 there have been the records of the Observatory, first at Liverpool itself and later at Bidston. I have already mentioned the early Hutchinson record (1768—1793) hitherto unreduced. Like Dalton's series, it gave a good deal of trouble, inasmuch as Hutchinson only began to observe out of doors in 1777, his thermometer being under a table on the roof of his four-storey house by the Old Dock. He read it twice daily, at 8 h. and 12 h., and a prolonged investigation was necessary of the properties of a shaded thermometer imperfectly protected from radiation, on a roof 40 ft. above the ground. It was extremely gratifying to find, however, that when the complex reduction was complete and when a decision had been reached on the probable correction to be given to a Merseyside thermometer adjacent to the little Liverpool of those days to bring it to the standard of the inland plain, the results agreed very well with those derived from contemporary records at Lancaster and Kendal. Accordingly, I think one can place a reasonable amount of trust in the figures given for mean temperatures from 1781 onward; appropriately enough, this was not only the year of the first cotton mill in Manchester, but also the foundation of this, the oldest Northern scientific society.

For the years 1753 to 1780 most of the values of mean temperature must as yet be described as estimates. For we have frequently to make the best possible fit of mean temperatures based on thermometers kept "indoors", a curious eighteenth-century habit followed by many amateur observers such as Vernon of Middlewich. Until 1777 Hutchinson, for example, kept a thermometer "at the top of the stairs leading to the

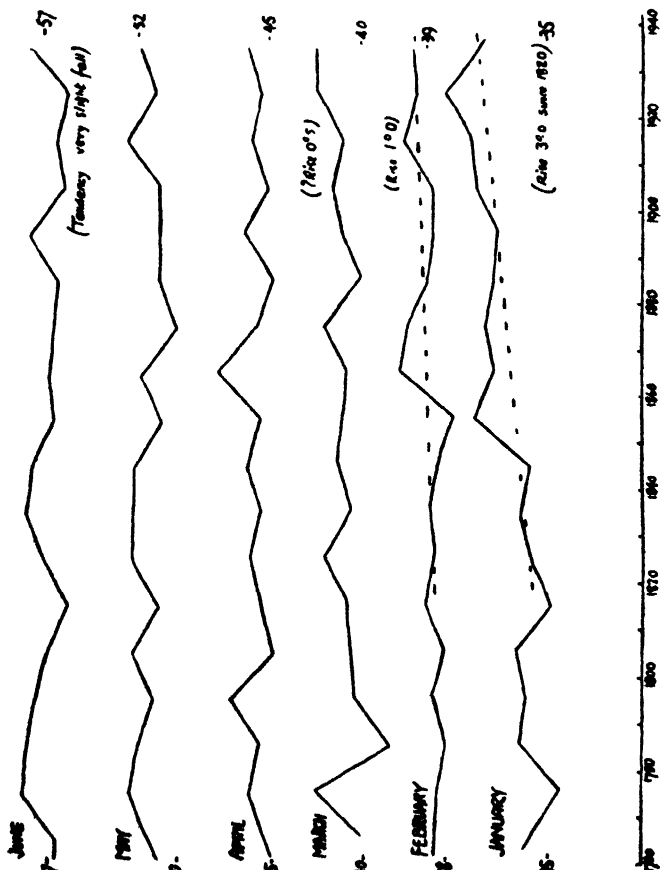
roof"; this indoor record partly overlaps an outdoor record kept by Dobson at the Liverpool Hospital not far away. From 1756 to 1759 daily observations are available from Carlisle; internal evidence suggests out of doors. I have had to fill up the gaps through 1755 and from 1760 to 1765 inclusive from more distant records kept in London and Scotland, associated with a journal kept in Dublin which gives little beyond wind directions and notes on the weather. I have not yet lost hope that some or all of the MSS. of a temperature record, which was probably kept in Carlisle between the years 1757—1783 or thereabouts, will be found to complete the series of observers since the early fragmentary contribution by Dr. Rogers of Bolton (1753—1754) and the Carlisle record from 1756 to 1759, which was also kept by a medical man, G. Smith.

Eighteenth-century temperature records are, however, so very rare that these figures appear to be worth giving. Further, while all the values before 1781 must be treated with much caution, they do enable us to provide, for Lancashire, one of the longest series of comparable monthly mean temperatures in the world. In Europe the most notable long series is that for the Stockholm region, which with the aid of Upsala carries us back to 1739. So much of this remarkable Lancashire series is due to the efforts of the early members of your Society that I feel it an especial pleasure to be able to present these results to their descendants. Tables of this kind provide endless possibilities for the statistician; they are of value to engineers and others, and may serve also to satisfy the curiosity of many with regard to the incidence of extreme seasons. The general fit with other long series (Edinburgh, Oxford, Durham) is good. I should like, however, to reiterate that while this series of values may be as good as one can expect, the errors may still be appreciable for earlier decades, bearing in mind all the imperfections of instruments and exposure and the bold assumptions necessary in making the reductions. With regard to the later part of the record, since 1846 or thereabouts, the mean temperature of the plain for every month has been derived with appropriate corrections from the results given at from four to eight stations between Mersey and Solway; it is very nearly given at present by adding 0.3° to the published mean for Leyland, or 0.1° to that for Hutton. Such a "mean for the plain" has the advantage

that in a hundred years' time it can still be derived from stations free from "urban effects" of the kind which nowadays cause the minimum temperature on a clear summer night to be about 10° higher in the centre of Manchester than that outside the city. (Manley, *Geogr. Journ.* **103,** 1944.)

The Trend of Lancashire Mean Temperature Since 1750.

Having derived with reasonable caution our table of mean temperatures, we may contemplate some of the results. Plotting the mean temperatures for each decade, we get the curves shown in Figs. 1 and 2.



"Lancashire": Trend of Decadal Means for each Month.

Fig. 1.

"Lancashire": Trend of Decadal Means for each Month.

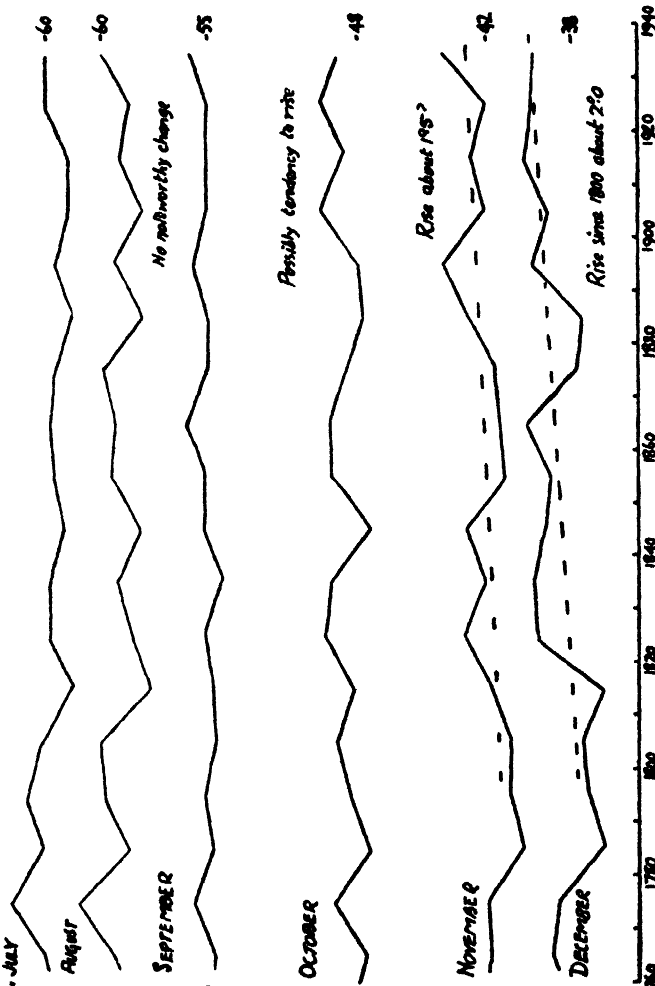


Fig. 2.

It is at once evident that while the overall trend of the summer months shows little or no real change, the winter months, especially December and January, show a decided rise since

about 1810 or 1820. The state of affairs is clearer if we show running ten-year means for the two extreme months January and July (Fig. 3).

"Lancashire": Trend of Monthly Mean Temperatures. Ten-Year Running Means.

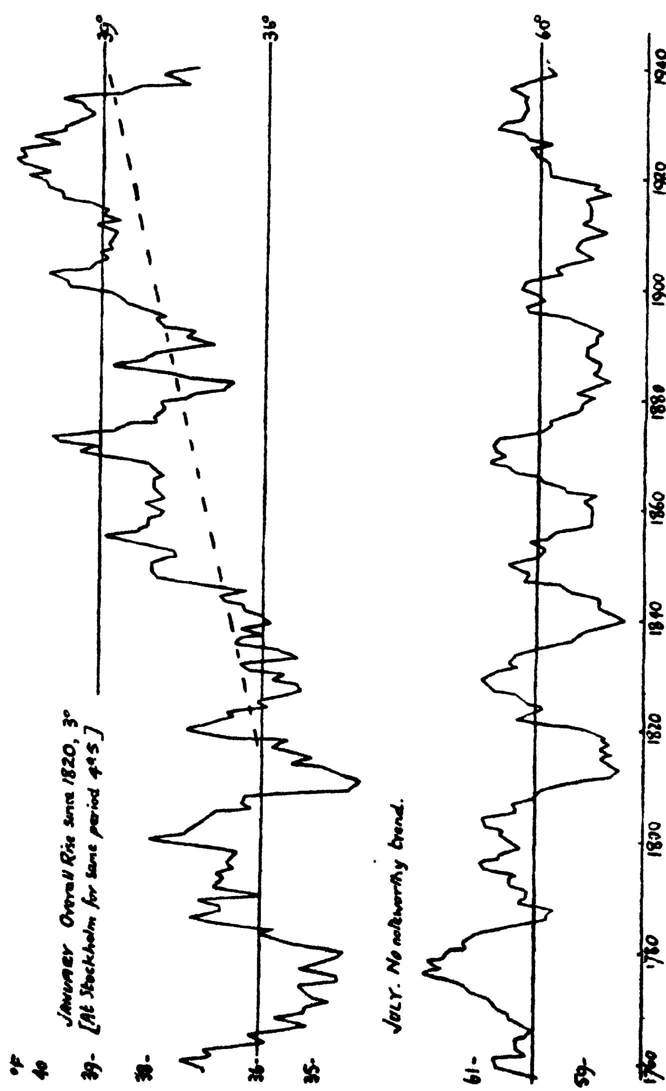


Fig. 3.

This is a remarkably interesting result; to which we may add that if we draw a line through the curve of running ten-year *annual* means we see that the mean for the whole year has risen by about 0.6° overall. But, of course, we are not absolved from cold winters; the downward trend of January as a result of 1940, '41, '42 and '45 is quite marked, and it remains to be seen whether the overall tendency since the "Napoleonic winters" will persist. Nothing, however, has approached the severity of January, 1814, or January, 1795.

The result is the more striking, as it compares remarkably well with the trend shown by the Stockholm means (Angstrom, *Ymer*, **59**, 1939) both in summer and winter; the annual mean shows a rise of about 0.9° since 1820. The rise in the Stockholm January temperatures is even more marked, amounting to about 4.5° F., compared with 3° for the same period in Lancashire; and much attention has been devoted by Scandinavian climatologists to these changes and tendencies in recent years, especially in connexion with the marked retreat of the Scandinavian and Icelandic glaciers.

It will at once be asked, what explanation is forthcoming? The fact that the rise of temperature is shown elsewhere means that we cannot ascribe it to the work of man in so greatly extending the towns—and the smoke—of Lancashire. Of course, the great increase in the area of Manchester has no doubt led to a local rise of temperature in the centre, as the Oldham Road and other data show, but this covers quite a small area in comparison with the whole county.

Attention has also been called to the marked diminution of the Arctic ice in recent years, shown by the increased length of the shipping season at Spitsbergen, as well as by what Ahlmann has called the "almost catastrophic" retreat of the glaciers. In this country the disappearance during September of the semi-permanent snow beds on Ben Nevis and the Cairngorms on more than one occasion during the "warm 1930's" agrees with the data from Norway. Scandinavian climatologists appear to be attracted by the view that the vigour of the atmospheric circulation, i.e. the horizontal transfer of heat, has increased. According to Angstrom this would have the effect of slightly lowering temperatures at the equator, but distinctly raising those of the temperate zones, especially in winter in higher

latitudes * It is readily conceivable that an increase in the vigour of the circulation would tend to check the stagnation of colder air in winter in those Scandinavian anticyclones which so often provide us with a long spell of cold easterly weather in winter In almost any English winter we can note several occasions on which the cold south wind derived from the Continent is gradually, or even suddenly, ousted by the oncoming milder south wind of Atlantic origin, January 4 of this year (1946) gave us a conspicuous example Whereas the great Lancashire snowstorm of January, 1940, was associated with a very mild air flow to the west over Ireland, that was unable to oust the Continental air from England We may observe the analogy with the conditions likely to prevail during the Pleistocene glaciation

But to speak of "increased vigour of the circulation", i e. more frequent depressions travelling further into the Continent or towards the Arctic, leaves us unsatisfied, very slight changes in the solar constant may have been effective, but we need much more information with regard to the transmission and absorption of radiation through the atmosphere It is, of course, noteworthy that " coarse " impediments to radiation such as those resulting from great volcanic eruptions and their accompanying high-level diffusion of fine ash have played their part in giving us " cold years " such as 1784, 1816 and 1912, these show in the tables, but apparently such hindrances soon cease to be effective We must await further work on the part of the physicists of the atmosphere

We may note, however, that the colder " Napoleonic winters " were associated with an increased frequency (shown by contemporary records) of winds from easterly points, all of which agrees with a greater tendency for Scandinavian anticyclones to develop and persist We may also assume that the average annual number of days with snow-cover leading to lower radiation temperature would be greater than now, and that all these effects would be more marked in December and January than during the later part of the winter. As for summer, our temperatures are in any case markedly under the dominance of the neighbouring seas, as the prevailing wind is from westerly points.

* Further references for those interested are available in Q J Roy Met S, 70, 1944, p. 218-9

Hence we might be tempted to assume that a possible slight present-day increase in wind and cloud, while diminishing the range from day to night, would make little difference to our mean temperatures ; if anything, it might tend slightly to lower them. This is exactly what has happened as far as one can judge from the records.

Now we may comment on some of the further effects associated with this amelioration of the winter averages. We cannot yet say whether the trend will continue ; further, it is to be noted from the curve that swings of considerable magnitude occur, one of which reflects the late Victorian tendency for colder winters. These fluctuations cover a narrow range—narrower than on the Continent, or in America ; but extremely effective to human perceptions, as the variations of temperature lie just across those which determine whether snow and ice do or do not persist. In a former paper (Q. J. R. Met. S., **65**, 1939) I explored the relationship between the frequency of snow-cover and the mean temperature of the month at a large number of British stations, based on the thirty years of available records. It became clear that if a sufficient number of years is taken the average expectation of snow-cover ranges from one " day " (morning observation at 9 h.) in a month with a mean temperature of 41° to over twenty " days " in a month with a mean of 32°. Accordingly, we can make an estimate of probabilities for the two decades 1801—1820, compared with the period 1911—1940. We shall find that on theoretical grounds the mean annual frequency of snow-cover at Leyland, over 1911—1940, should be 8.3 days ; by observation (1914—1940) it was 8.8. If we assume that the chances of snowfall at any given temperature were similar in 1801—1820 to those prevailing now, the mean temperatures for that period indicate that snow-cover should have been observed on an average of about 24 days—nearly three times the present expectation, and an average slightly above that which we nowadays expect at Buxton. Such a figure has only occurred at lower levels three or four times since our records began in 1912, namely, in 1917, 1919, 1940 and perhaps 1941 and 1942. If we make an estimate on similar principles for the period 1871—1900—the " late Victorian winters "—we shall get an expectation of about 15 days in the region represented by Leyland.

None of these figures is large, but the Lancashire plain is not a snowy place. They must not be treated without reserve, especially for past decades; but they do indicate that over considerable groups of years the impression gained of the Lancashire winter must have varied considerably. Incidentally the expectation of snow-cover at higher levels would increase, but not in the same proportion; on the Rossendale and Bowland moors at 1,000 feet the average expectation at present appears to vary from about 20 to 30 days from west to east; in the " Napoleonic " period a figure of the order of 40 to 50 might, by and large, have applied.

The freezing-over of Windermere appears to be a good index of real severity; it was covered in 1814 and 1895, and possibly in 1740. As far as I can gather it was not quite covered in 1785 and 1795. Someone might well search the older records for further evidence. Certainly in 1838 the Mersey ferries were nearly stopped by ice at Liverpool, and in 1776 Hutchinson records " skating on the salt-water dock ".

These old temperature records scarcely allow us to do more than guess at the extremes of temperature to which Lancashire may be subject. Thermometers were generally read at fixed hours; instruments were more sluggish than now. Undoubtedly minima below zero occurred; for example, at Kendal (1796), Carlisle (1814), and elsewhere. Maxima appear to have been very similar to those of to-day. From the extremes derived under standard conditions of exposure since 1880 it appears that once or twice in a century or so some frosty valley inland may experience $-10°$, and an upper limit for South Lancashire may lie in the region of $95°$. Even on the coast at Blackpool $-1°$ was recorded in 1881; much depends on the freedom with which the cold air of the inland valleys may flow down to the coast. Inland, $-7°$ near Garstang (1881), $-8°$ near Carlisle (1892), and incidentally $-6°$ at Ambleside (in 1940) are noteworthy. It must be emphasised that such temperatures are often very local and occur in the bottoms of broad exposed valleys. Stonyhurst, well above the valley floor, has never in a hundred years recorded below $+4°$.

Hence in our climate relatively small temperature differences are likely to give rise to very distinct impressions in people's minds, especially if they lie in the direction of greater cold;

neither must we forget that an increasing number of us live in cities and are less affected than were our forefathers. It is clear, however, psychological and other considerations apart, that some at least of their views regarding colder winters were justified. It is easy to see from the tables that they also enjoyed mild winters from time to time much as we do ; but that on the whole such winters were not so frequent. With regard to the rest of the year, I do not think we have yet enough evidence to show whether the incidence of spring and autumn frost differed appreciably from the present over any group of years. But it is worth adding that Dalton's papers undoubtedly indicate that snowdrifts were as a rule more persistent on Helvellyn in his day than we are accustomed to find nowadays, e.g. in June-July.

Rainfall.

If we ask ourselves about farming conditions in Lancashire we are immediately led to consider rainfall. It appears that the trend of Lancashire rainfall can be illustrated with some success, principally by reference to the long series of records kept at Manchester and Kendal, especially those maintained by Dalton and his brother. Reduction of early rainfall observations presents, however, almost as many complexities as that of early temperature records, and I must leave the details for a forthcoming paper. Suffice it to say here that the fluctuations of rainfall broadly resemble those published by Dr. Glasspoole for the country as a whole (*Meteorological Magazine*, 1928) for the past two centuries, but provisionally it appears that the range of variation is greater. It certainly appears that a Lancashire man between 1820—1840 would have an impression of a distinctly wetter climate than over the period 1885—1905, or since 1932 ; on the other hand the 1780's, the first decade of the new century, and the 1850's tended to be dry. There is no reason to suppose that there has been any marked change in "rainfall expectations" since 1750.

Examination of the early records indicates that the proportion borne by the average for each month to that for the year shows little difference. Expressed in percentages of the annual total, we have for Manchester :

Dalton 1794—1840 (Jan.-Dec.)	6.4	6.9	6.5	5.9	6.9	7.3	10.5	9.8	9.0	10.6	10.5	9.7
"Standard," 1881—1915 ...	7.9	6.1	7.1	6.1	6.7	8.3	10.4	10.9	7.6	10.4	8.3	10.2

January appears to have been rather drier, a result we might expect in association with the evident tendency for colder Januaries. September and particularly November tended to be wetter. We must not stress these differences too much; even in the last thirty years April has shown a marked tendency to give more rain than during the previous thirty years. Such comparisons as I have been able to make indicate that the outstandingly dry and wet years bear much the same relationship to the normal. The phenomenally wet year 1792 (with about 150% of the provisional overall average for Lancashire) was approached in 1872 (140%) and 1928 (135%); 1877, 1836, 1823, 1789 and 1768 were also noteworthy. The driest year, 1887, gave 63% of the long average; it was followed by 1788 (about 72%) and 1855 and 1902 (73%). 1933, 1937, 1941; 1826, 1803, 1780 and perhaps 1757 were also outstanding in this respect. These figures will serve as a reminder that our chances of extremely wet or dry years seem to be very much the same; further, it is to be observed that exceptionally wet years do not necessarily fall in a wet period, and vice versa. For example, 1852 was a very wet year in a dry decade; 1826 and 1921 were very dry years in wet decades.

For the earlier years these figures are provisional; they must yet be examined with more relation to the rest of the country, and are merely given here as indications.

Some Conclusions.

I am conscious of the fact that a paper such as this may be regarded as old-fashioned; your Society had plenty of them a hundred years ago. Yet it should do no harm to remind ourselves of the splendid contributions of our forefathers. They would be the more pleased to know that their years of assiduous observation were bearing fruit, and that in the smoky Lancashire of our day we do not suffer from impaired vision of the merits of the climate we share.

Some here will ask for evidence of periodicities, a type of investigation long fashionable, of which Baxendell of Southport was a well-known Lancashire exponent. I shall only remind you here of Professor Brunt's paper on "Climatic Cycles" in the *Geographical Journal* for 1937, in which he pointed out the risks of coming to premature conclusions which will not stand

the test of time. Rather we may look to the historians in order to find out whether the climate of Lancashire became colder from 1600 onward in what Matthes has called "The Little Ice Age". Many of our earlier notions have been upset by the recent evidence from Scandinavia that the greatest advance of the glaciers since the waning of the Ice Age has taken place since 1600. There is much room for further work in this field in our own island. Moreover, the ultimate explanation of the complex problems of the atmosphere still provides endless tasks for the physicist; it may be that we have directed our attention too much in the direction of the nucleus, and that some physicists might again turn to " natural philosophy " as it was once called, including that of the atmosphere.

Lancashire got off to a splendid start in meteorology; yet no one can deny that we need more men with the training, and with an immediate and keen interest in the weather. In Britain our universities have done far too little to encourage the study of meteorology in any form. Meteorology has many branches and applications, and there is room for many workers besides the physicists. Nowhere should there be a more ready recognition of the need for climatic knowledge than in a city such as this, which is interested in the export of goods—and services—to many lands. Manchester has already published through this Society the work of so many of the observant pioneers whom we have had in mind in this paper. Lancashire is still capable of producing the type of mind we want in meteorology. Most of us who walk over the moors, who lean against the wind, or who appreciate the struggle of the lupins to overcome that terrible sunshine record of Ancoats, know what the weather means to us.

We can appreciate the emotions of Dalton, enjoying with his mathematical brain his Thursday game of bowls, and the breezy warmth of the summer afternoon when the fleets of fine-weather cumulus came over the Cheshire plain. We can picture that remarkable man Hutchinson—he who enlivened Liverpool in his younger days by his exploits as a privateer captain. Daily at noon he tried, by running with a silk handkerchief, to measure the speed of the wind as it blew along the dock-side—anyone who knows the Pierhead at Liverpool will appreciate that. We can pass Seathwaite and recall that Miller of Whitehaven was the first man to establish a basis for our theories of mountain

rainfall. Peter Crosthwaite of Keswick joined with Dalton in the first good measurements of the height of the aurora. Dobson of Liverpool attacked the problem of evaporation; Vernon of Old Trafford tackled barometric fluctuations; under Schuster Manchester University initiated upper-air observations. And in the great tradition your own Dr. Ashworth has attacked on original lines the problem of the smoke.

It takes many men to build up a science; and I would say let not Lancashire forget its traditional interest in the weather, or allow meteorological inquiry to languish for lack of support. Secondly, no body in the North has done more for meteorology than this Society in the past; I should like to express the hope that it will continue to flourish and to encourage one of the great observational sciences. Thirdly, a distinguished meteorologist has said: "It is probable that all great discoveries and advances first germinate in the minds of men under 25, even if they are worked out in more mature years". For that reason we should like to see the universities do more to train young men to embark on the splendid complexities of the study of the weather in all its branches. In a country—indeed in a county—renowned for its weather this may well be emphasised.

[Detailed references to sources of early meteorological observations, to methods used in correcting them to a common standard, and to other papers dealing with records before 1850, are appended to the address cited above: Q. J. Roy. Met. S., January, 1946.]

TABLE I—II.

REPRESENTATIVE VALUES OF MONTHLY MEAN TEMPERATURE FOR THE LANCASHIRE PLAIN.

I. Estimated Means for the period 1753—1780. °F.

(Interpolated values based on more distant records are shown in brackets).

	Jan.	Feb.	Mar.	April	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Year
1753	—	—	—	—	—	—	—	—	—	48	41	40	—
54	39	38	39	43	51	54	55	59	54	(50)	(45)	(39)	47.2
55	36	34	(40)	(46)	(48)	(58)	(57)	(58)	(51)	(49)	(39)	39	46.5
56	40	41	44	42	47	56	60	58	54	49	39	36	47.2
57	31	39	40	43	49	57	63	56	56	47	45	37	46.9
58	36	39	41	44	56	57	58	60	52	46	43	39	47.4
59	44	43	43	46	52	58	63	59	55	49	40	34	48.8
60	(33)	(37)	(42)	(48)	(52)	(57)	(61)	(60)	(58)	(47)	(42)	(40)	48.1
													47.4

I. Estimated Means for the period 1753—1780—*continued*.

	Jan	Feb.	Mar	April	May	June	July	Aug.	Sept	Oct	Nov	Dec	Year	
1761	(39)	(39)	(42)	(45)	(53)	(58)	(61)	(61)	(56)	(47)	(42)	(39)	48 5	
62	(39)	(38)	(38)	(46)	(54)	(58)	(62)	(57)	(54)	(47)	(43)	(41)	48 1	
63	(32)	(41)	(41)	(45)	(50)	(57)	(58)	(58)	(53)	(47)	(42)	(42)	47 2	
64	(39)	(39)	(39)	(45)	(53)	(57)	(61)	(59)	(53)	(47)	(40)	(38)	47 5	
65	(41)	(33)	(41)	(45)	(52)	(56)	(60)	(60)	(56)	(48)	(39)	(35)	47 2	
66	34	35	40	47	49	57	60	61	54	49	43	39	47 3	
67	32	43	41	45	49	55	57	60	57	47	44	38	47 3	
68	33	41	42	47	54	57	60	59	52	49	42	40	48 0	
69	36	37	42	47	52	55	63	58	54	47	42	38	47 7	
70	37	40	36	42	50	55	59	60	58	48	41	38	47 0	
														47 6
1771	33	38	38	42	54	58	60	57	53	48	43	41	47 1	
72	34	35	40	44	50	61	63	60	54	53	44	40	48 2	
73	39	36	44	47	50	58	61	63	53	49	41	38	48 3	
74	33	40	44	48	52	57	61	61	54	51	40	38	48 3	
75	40	43	43	50	54	62	62	60	57	48	40	40	49 9	
76	30	38	43	49	52	56	61	58	55	50	42	39	47 7	
77	35 0	35 5	44 0	45 0	53 0	56 5	58 5	59 5	58 0	49 0	44 0	35 5	47 8	
78	34 5	37 5	39 5	46 0	53 5	59 0	62 5	62 5	53 5	45 0	43 5	42 5	48 3	
79	37 0	46 5	45 0	47 5	52 5	58 5	64 5	65 0	58 5	50 5	42 0	36 0	50 3	
80	30 0	35 0	46 0	42 5	54 5	57 0	62 5	64 0	60 0	47 0	39 0	36 5	47 9	
														48 4

II. Monthly Mean Temperature, 1781—1945 °F

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year	
1781	33 5	39 5	43 0	50 5	53 5	60 5	64 5	64 0	57 0	51 5	43 0	40 5	50 1	
82	41 0	35 0	39 0	40 0	46 5	57 0	59 0	55 5	55 0	44 5	35 0	36 0	45 3	
83	36 5	39 0	37 5	50 0	49 0	57 5	64 3	59 0	53 5	47 5	41 0	35 0	47 5	
84	29 8	33 3	36 0	41 5	53 5	55 7	57 7	55 7	57 5	45 0	40 8	31 0	44 8	
85	38 0	32 0	33 5	46 5	53 0	60 5	61 0	55 0	55 0	46 7	41 8	36 2	46 6	
86	36 1	37 3	35 6	46 8	50 7	60 5	57 9	57 7	52 0	44 0	36 0	36 0	45 9	
87	38 6	42 5	44 0	45 0	53 0	56 5	60 0	58 5	54 5	49 3	39 5	37 8	48 3	
88	39 1	38 3	37 9	48 0	56 5	59 5	60 8	59 5	55 5	49 0	42 8	31 5	48 2	
89	34 3	40 8	35 9	45 0	53 6	56 7	59 1	62 3	54 8	46 5	40 2	43 0	47 7	
90	39 8	44 0	42 7	42 9	52 7	56 8	57 5	58 7	53 0	50 7	42 7	38 7	48 3	
														47 3
1791	39 4	40 5	43 5	48 5	50 8	58 0	59 0	59 3	56 2	47 5	41 6	33 0	48 1	
92	35 3	40 2	42 3	49 0	49 5	55 6	59 3	61 8	52 3	47 4	44 8	39 3	48 1	
93	36 5	39 8	39 0	43 2	51 5	56 6	63 0	57 5	52 0	52 0	41 5	41 0	47 8	
94	35 0	43 7	44 0	50 1	51 5	61 0	64 0	59 2	54 0	48 8	42 0	38 3	49 3	
95	26 0	33 0	39 0	46 0	50 6	56 0	59 5	61 5	60 0	52 4	38 5	43 8	47 2	
96	45 0	39 8	39 0	50 5	50 1	56 2	57 8	60 0	57 5	45 8	39 3	30 5	47 6	
97	38 0	39 5	39 3	45 0	51 2	56 8	62 8	60 5	[illegible]	46 3	39 2	40 0	47 7	
98	38 0	38 0	40 5	50 5	55 4	62 3	61 0	60 4	54 9	49 5	40 0	34 3	48 7	
99	34 8	36 4	37 6	40 8	48 4	57 5	58 5	57 3	55 0	46 5	40 9	34 3	45 7	
1800	36 6	36 1	39 5	48 0	54 0	57 2	64 2	60 9	56 1	48 2	40 5	37 4	48 2	
														47 8
1801	40 4	40 3	43 5	46 7	53 2	57 8	60 5	62 0	56 0	49 4	39 7	33 5	48 6	
02	34 7	37 5	41 5	47 0	50 9	55 3	55 4	61 5	56 5	50 0	42 3	39 0	47 6	
03	35 2	38 3	42 8	47 8	50 0	55 8	62 8	59 4	51 9	48 5	39 5	37 7	47 5	
04	42 1	36 7	39 7	43 5	55 1	59 7	60 3	59 0	57 3	50 8	43 0	35 4	48 5	
05	35 6	38 5	43 5	46 5	50 3	55 7	60 9	60 7	57 4	45 5	39 9	37 7	47 7	
06	37 8	38 5	41 2	44 7	53 0	57 3	59 8	60 5	54 8	50 4	45 0	43 5	48 9	
07	36 7	37 5	36 5	45 3	52 5	56 4	61 9	61 1	48 7	51 3	35 8	34 6	46 5	
08	35 9	36 6	37 1	41 6	55 7	58 7	64 8	60 7	53 9	43 6	41 8	36 1	47 2	
09	33 4	40 5	42 3	41 0	55 0	55 4	59 0	57 5	53 5	50 3	40 3	39 0	47.3	
10	35 8	37 4	39 4	46 1	47 4	57 6	58 0	58 0	55 9	48.1	40 3	38 0	46 8	

II. Monthly Mean Temperature, 1781—1945—*continued*

	Jan.	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year	
1811	34.4	39.4	44.3	47.3	54.0	56.5	60.1	57.4	55.6	53.0	45.8	36.6	48.7	
12	36.3	40.6	37.2	41.1	51.2	55.0	56.4	57.4	55.9	48.3	40.2	34.8	46.1	
13	35.3	42.3	44.4	45.4	52.1	56.2	58.1	56.8	53.9	45.6	38.8	36.6	47.1	
14	25.6	34.6	37.5	48.7	47.5	53.2	59.5	57.4	54.7	45.4	39.9	38.1	45.2	
15	32.5	42.9	43.6	45.4	53.4	56.6	58.1	58.1	55.1	50.1	37.4	35.0	47.4	
16	36.6	36.1	38.4	43.3	49.2	54.1	55.3	56.9	52.1	49.8	38.8	36.8	45.5	
17	39.8	42.6	41.2	47.0	47.2	57.7	56.3	55.4	54.9	42.6	47.6	35.1	47.3	
18	38.9	36.6	38.6	42.6	52.4	60.1	63.1	57.8	54.8	53.2	48.5	38.9	48.8	
19	39.4	38.6	43.6	46.3	51.0	54.8	60.9	62.9	55.0	47.6	38.4	33.1	47.6	
20	30.9	38.4	39.8	47.4	51.6	55.2	59.9	57.2	53.8	45.6	42.0	40.5	46.9	47.1
1821	38.3	36.4	41.5	48.4	47.9	54.4	57.9	60.0	57.6	50.3	46.2	42.4	48.4	
22	40.2	42.9	44.9	46.2	53.9	61.2	58.8	57.8	53.3	50.3	46.0	35.0	49.2	
23	31.8	36.5	40.8	43.3	52.7	52.9	56.4	56.3	53.5	46.4	44.6	39.7	46.2	
24	40.0	40.3	40.0	45.3	51.2	56.2	60.0	58.2	55.7	47.7	42.8	39.5	48.9	
25	37.7	38.5	40.9	47.1	52.5	56.5	61.8	60.6	58.6	50.8	40.2	39.7	48.7	
26	32.0	42.9	43.1	47.0	52.7	62.9	63.1	62.1	56.0	51.0	39.2	41.7	49.5	
27	35.1	33.6	41.7	47.7	53.1	57.3	60.8	57.8	56.1	52.8	43.5	43.6	48.6	
28	40.3	40.7	43.4	46.0	53.6	58.9	59.7	59.4	57.0	49.5	44.7	45.0	49.9	
29	32.7	39.3	39.4	43.7	54.1	58.2	59.2	56.8	51.4	46.3	40.2	35.4	46.4	
30	31.7	35.8	45.0	47.5	53.0	53.8	60.0	56.0	53.2	49.8	44.0	35.2	47.1	48.2
1831	34.5	39.5	44.3	48.3	53.5	57.5	61.6	61.6	56.0	54.3	41.[illegible]	42.2	49.7	
32	37.3	38.5	43.0	47.5	50.9	58.6	60.4	58.8	56.5	50.9	41.3	40.7	48.7	
33	33.3	41.0	39.6	45.5	58.5	57.3	60.9	57.2	53.7	49.3	43.4	43.2	48.6	
34	44.0	42.1	44.4	45.8	54.8	58.6	62.5	60.5	55.7	50.8	41.1	42.0	50.4	
35	35.8	41.5	42.4	46.9	50.9	57.7	59.5	61.2	54.9	47.3	43.5	38.8	48.4	
36	38.7	38.5	41.5	45.1	52.2	58.8	58.1	57.0	52.6	47.3	40.8	38.6	47.4	
37	35.9	39.6	35.8	39.9	50.0	59.1	61.5	59.5	53.7	50.3	40.9	41.3	47.3	
38	29.9	32.0	40.2	42.5	50.3	56.9	59.3	58.0	54.2	48.8	39.5	39.1	45.9	
39	36.5	38.3	38.9	44.1	50.6	57.6	58.9	58.4	53.9	48.9	45.0	38.0	47.4	
40	39.1	38.3	39.3	50.0	52.3	56.6	56.5	60.1	51.7	45.5	42.5	35.6	47.3	48.1
1841	33.7	37.6	45.1	46.0	53.9	55.2	56.8	57.5	55.6	46.8	40.4	39.5	47.3	
42	32.5	38.7	42.5	46.8	52.8	58.8	57.8	61.8	55.6	44.2	41.3	45.2	48.2	
43	38.0	35.5	41.3	47.0	50.8	55.5	58.3	58.9	57.5	44.8	41.0	45.7	47.9	
44	38.0	34.3	39.3	48.0	51.5	57.4	59.0	55.8	56.0	47.9	42.5	32.2	46.8	
45	36.3	34.0	35.7	48.0	49.5	57.6	57.6	56.1	52.5	49.0	43.5	39.8	46.6	
46	42.5	42.8	42.3	45.7	53.1	64.0	60.8	62.3	58.3	49.0	44.1	32.6	49.8	
47	36.3	36.6	42.3	43.5	53.0	57.0	63.1	58.1	52.5	50.2	45.9	39.5	48.2	
48	33.8	41.9	41.9	46.2	56.0	58.0	59.4	55.6	55.0	49.0	41.8	41.5	48.3	
49	37.9	42.0	42.7	43.3	53.1	55.8	59.1	59.0	55.4	47.4	44.0	37.5	48.9	
50	32.9	42.7	40.7	48.1	50.2	59.3	61.4	57.2	53.8	45.5	44.6	40.0	48.0	47.9
1851	41.3	40.1	42.4	45.0	50.0	56.3	58.1	59.0	54.5	50.7	37.3	40.8	48.0	
52	40.3	40.1	41.7	47.2	50.9	55.0	64.8	60.3	54.9	45.4	44.7	44.8	49.2	
53	40.5	33.1	38.3	44.8	51.3	57.3	57.7	57.4	53.7	49.6	41.3	34.4	46.7	
54	37.8	39.6	44.6	48.0	50.4	55.4	58.7	58.8	57.7	48.3	40.9	40.8	48.4	
55	36.5	28.9	37.6	44.5	46.9	54.9	61.4	59.0	55.1	48.6	41.5	36.0	45.9	
56	37.9	41.3	40.5	46.5	49.0	55.0	57.8	62.2	54.3	51.6	40.0	39.3	47.9	
57	36.5	39.9	41.4	45.5	50.4	60.0	60.2	62.8	57.7	52.1	44.4	45.1	49.8	
58	38.7	36.0	40.7	45.4	51.6	61.1	57.7	60.1	57.7	48.5	40.3	40.7	48.2	
59	41.3	41.7	44.8	44.5	54.1	57.8	62.9	60.3	54.6	48.7	40.8	34.2	48.8	
60	37.8	35.2	39.9	43.2	52.1	54.0	57.6	55.0	51.9	49.0	40.1	34.0	45.8	47.0

II. Monthly Mean Temperature, 1781—1945—*continued*

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year	
1861	35 3	40 4	43 0	45 7	49 8	58 6	58 4	59 7	55 0	52 1	38 8	38 9	48 0	
62	38 6	41 1	41 1	47 1	53 5	53 6	56 3	57 9	54 5	49 7	37 3	43 5	47 9	
63	40 2	42 5	44 4	47 5	50 5	55 6	58 5	59 2	52 9	49 6	45 0	43 0	49 1	
64	36 0	36 0	39 8	47 9	54 0	55 3	58 8	56 6	55 2	49 3	42 4	38 9	47 5	
65	35 5	35 7	37 6	50 3	53 9	59 2	61 4	58 8	61 0	49 1	43 1	42 4	49 0	
66	42 2	39 7	39 9	47 0	49 5	59 1	58 9	57 9	54 4	50 9	44 1	42 5	48 8	
67	33 4	44 0	37 5	47 7	52 0	56 5	58 3	61 2	56 3	48 4	40 3	38 6	47 9	
68	39 2	43 3	44 3	47 3	55 4	58 1	64 0	62 0	57 8	47 0	40 9	44 1	50 3	
69	42 3	45 2	39 3	49 6	47 7	55 3	62 6	59 0	57 4	49 6	42 1	36 9	48 9	
70	37 6	37 5	41 1	48 7	53 0	57 9	62 1	60 5	55 8	48 7	40 0	33 2	48 0	48 5
1871	32 8	42 7	45 3	47 0	52 5	55 2	58 7	62 3	54 3	49 5	38 7	39 0	48 2	
72	40 9	44 1	44 1	46 1	48 6	55 9	61 3	59 0	54 7	47 0	44 2	40 7	48 9	
73	40 9	35 7	41 7	45 9	49 0	56 8	59 9	58 9	53 1	48 0	42 8	42 6	47 9	
74	42 0	39 4	44 4	49 3	49 5	56 5	62 0	58 3	56 0	50 2	42 4	31 0	48 4	
75	42 9	37 1	41 0	48 1	53 3	56 4	59 0	60 3	58 5	48 2	41 3	39 7	48 8	
76	38 5	40 2	40 2	46 2	49 4	57 0	61 4	61 0	54 8	52 5	42 5	42 2	48 8	
77	41 1	42 7	40 6	44 0	48 0	58 3	57 6	58 6	52 4	48 6	44 5	40 4	48 1	
78	40 0	41 5	41 4	48 0	52 8	58 2	61 8	61 0	55 9	50 4	38 0	30 0	48 3	
79	30 5	36 8	40 3	42 1	47 9	54 9	56 2	57 8	54 0	47 9	40 1	33 3	45 1	
80	34 7	42 2	42 4	46 0	49 9	56 4	58 8	61 5	57 6	44 0	40 9	39 7	47 8	48 0
1881	28 3	37 1	40 7	44 7	52 9	55 2	59 0	56 2	54 8	45 5	46 8	38 3	46 6	
82	41 5	43 3	44 7	46 9	52 1	54 9	58 8	58 3	53 7	49 9	41 8	38 0	48 7	
83	39 4	41 9	35 5	46 1	50 3	56 4	57 5	58 3	56 0	48 9	42 2	40 1	47 7	
84	43 1	41 1	43 5	45 2	51 4	56 3	60 5	62 0	57 5	48 8	41 1	38 8	49 1	
85	37 4	41 3	39 6	45 3	47 1	55 6	59 6	55 6	52 9	44 9	42 1	38 2	46 6	
86	35 3	35 5	39 4	45 3	48 9	55 8	59 3	59 3	55 5	51 8	43 8	34 8	47 1	
87	36 5	39 1	38 1	42 8	48 6	58 9	61 5	59 0	53 0	44 6	40 0	36 0	46 5	
88	38 4	35 8	37 2	43 3	50 5	55 1	56 1	56 4	53 5	46 8	45 2	40 9	46 6	
89	39 1	37 7	40 2	44 6	55 2	59 6	58 9	58 0	54 5	47 0	44 2	38 1	48 1	
90	41 5	37 8	42 9	44 5	53 1	55 6	57 4	56 7	58 4	49 4	41 9	31 8	47 6	47 5
1891	35 1	40 6	38 8	42 5	49 2	58 3	58 8	57 0	57 6	48 6	41 6	38 8	47 2	
92	36 0	38 3	37 2	44 7	51 8	55 0	57 5	58 4	53 7	44 7	43 3	34 8	46 3	
93	36 7	40 2	44 7	50 4	54 6	59 5	60 8	62 5	54 7	49 5	41 4	41 1	49 7	
94	38 3	40 7	44 6	49 3	48 0	55 5	60 4	57 0	52 9	48 2	46 4	41 0	48 5	
95	31 9	29 0	40 6	46 4	53 5	57 5	58 2	60 2	60 0	44 3	44 7	38 7	47 1	
96	40 9	40 7	42 9	48 1	53 7	60 3	59 5	56 9	55 2	43 7	40 0	38 6	48 4	
97	34 8	41 5	43 0	44 2	49 3	58 1	60 5	61 0	53 2	50 4	46 1	40 6	48 5	
98	44 2	40 4	39 8	47 2	49 8	56 2	58 2	60 5	58 5	52 2	44 2	44 9	49 7	
99	40 2	40 9	41 6	45 6	48 8	59 5	61 2	63 2	54 6	48 4	47 9	35 5	48 9	
1900	39 7	35 9	38 7	46 5	50 1	58 3	62 4	58 3	56 2	49 4	44 7	44 6	48 7	48 3
1901	38 5	36 4	39 5	47 2	53 0	55 9	64 0	59 5	57 1	49 5	41 2	37 9	48 3	
02	40 0	34 5	43 [illegible]	[illegible] 3	47 4	56 7	56 9	56 6	55 0	49 1	44 3	40 1	47 5	
03	38 9	44 5	41 [illegible]	[illegible] 2	51 6	55 4	58 5	57 2	54 9	50 0	43 3	37 5	48 3	
04	39 [illegible]	37 7	39 [illegible]	47 0	50 8	55 4	61 2	58 4	54 9	49 4	42 0	37 9	47 8	
05	39 1	40 7	43 9	44 4	51 1	58 2	61 4	57 8	53 7	44 4	40 7	41 6	48 1	
06	41 1	37 3	40 7	44 8	49 9	57 4	58 5	60 6	56 4	50 7	44 7	37 1	48 3	
07	38 9	36 7	43 0	45 4	49 9	53 6	56 9	56 4	56 4	49 2	43 1	39 5	47 4	
08	36 7	41 2	39 5	43 2	53 3	56 7	59 2	57 5	55 3	54 0	44 6	38 5	48 4	
9	38 5	38 2	38 4	47 2	50 6	53 2	57 3	58 2	53 0	49 8	40 2	38 1	46 0	
10	37 5	40 5	43 6	44 5	51 8	57 9	57 7	58 6	54 2	50 6	37 4	43 0	48 1	47.9

II. Monthly Mean Temperature, 1781—1945—*continued*

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year	
1911	39 5	40 2	41 5	45 4	55 1	57 1	62 4	63 5	55 6	48 4	42 5	42 5	49 5	
12	38 1	40 9	44 5	47 8	52 0	56 5	60 2	54 5	51 8	47 4	43 2	43 1	48 3	
13	39 2	41 1	42 3	46 4	51 5	56 4	58 0	58 6	57 1	51 1	46 6	41 0	49 1	
14	38 9	44 6	42 4	9 4	50 5	57 1	59 9	60 1	55 9	50 1	43 8	39 5	49 3	
15	38 9	39 6	41	4[illegible] 1	50 5	56 9	57 3	58 5	55 9	48 0	36 0	40 0	47 4	
16	45 3	38 9	37 9	46 2	51 6	53 1	59 0	60 8	55 6	50 3	44 5	35 6	48 2	
17	35 1	33 5	37 5	41 1	53 7	57 4	60 6	59 4	57 0	45 2	45 8	36 8	46 9	
18	39 1	44 0	42 1	45 1	54 4	54 8	58 6	60 4	52 9	48 4	41 8	43 5	48 8	
19	37 4	36 1	37 6	44 8	55 8	56 5	57 1	58 4	54 5	46 2	37 4	40 9	46 9	
20	40 6	43 1	44 5	46 4	52 3	57 3	57 0	56 5	54 9	51 3	45 2	39 2	49 0	
														48 4
1921	44 7	41 1	44 5	46 1	51 5	57 4	63 0	58 5	56 5	55 3	40 5	43 6	50 2	
22	38 1	39 9	40 5	41 7	52 9	55 5	55 7	55 9	53 5	47 1	43 3	42 2	47 2	
23	42 4	41 3	44 3	45 3	47 2	53 8	62 1	57 9	53 8	49 0	38 5	38 3	47 8	
24	40 0	38 4	39 3	43 5	52 1	56 1	58 7	56 9	55 8	50 0	44 2	44 7	48 3	
25	41 7	40 7	41 2	45 4	52 3	58 2	61 8	59 4	52 4	50 3	37 1	36 6	48 1	
26	40 7	43 8	43 1	48 9	49 6	55 9	62 8	60 6	57 0	46 2	41 7	39 9	49 2	
27	40 2	39 5	44 7	45 4	50 8	53 5	60 8	60 2	54 4	50 8	42 8	35 7	48 2	
28	40 9	42 5	42 9	47 6	51 3	54 1	58 4	59 2	54 5	49 6	45 2	38 3	48 7	
29	34 9	33 8	43 3	44 2	52 1	55 2	59 6	58 6	57 3	48 7	43 9	41 9	47 9	
30	41 3	36 3	41 2	46 7	50 9	58 5	58 6	59 4	56 3	50 5	43 1	39 7	48 5	
														48 4
1931	37 2	38 8	39 3	45 8	52 2	56 6	59 1	57 3	52 7	47 7	46 1	41 9	47 9	
32	43 3	38 3	41 0	43 9	50 3	57 2	60 5	61 4	54 8	47 1	43 8	42 3	48 7	
33	36 3	39 6	44 3	47 4	53 3	59 6	62 9	62 6	58 5	50 2	42 0	35 5	49 3	
34	39 9	39 9	40 5	46 0	51 1	57 7	63 7	58 8	57 5	50 8	42 3	46 4	49 5	
35	40 0	42 4	44 2	46 7	50 0	58 7	61 0	60 7	55 9	48 7	44 3	36 5	49 1	
36	37 9	36 8	44 8	43 2	52 5	57 7	59 2	60 0	57 5	49 2	42 1	41 6	48 5	
37	41 2	41 2	38 3	48 2	53 4	56 2	60 1	61 2	55 3	50 1	41 3	37 0	48 6	
38	42 1	41 5	47 5	45 9	51 1	56 2	57 8	60 2	56 3	50 7	48 5	40 0	49 8	
39	38 8	41 5	42 7	47 2	52 4	57 1	59 5	61 4	56 9	46 3	46 9	38 1	49 1	
40	29 8	36 6	42 1	47 0	53 9	61 0	58 2	58 8	54 0	49 1	44 3	39 4	47 9	
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1941	32 7	37 6	41 1	4[illegible] 0	49 1	58 0	61 9	58 1	58 5	51 2	43 5	42 3	48 1	
42	34 5	32 6	41 2	48 4	51 3	56 5	58 9	61 1	55 9	50 6	41 0	43 7	48 0	
43	39 9	43 4	43 8	49 8	51 9	57 1	60 2	59 6	55 3	51 0	43 7	38 6	49 5	
44	42 2	39 1	41 3	49 6	51 2	55 3	60 7	61 3	53 9	48 4	42 6	39 1	48 7	
45	32 6	44 0	46 2	49 5	52 7	57 6	61 4	60 2	57 5	53 4	45 4	40 1	50 1	

TABLE III. WARMEST AND COLDEST MONTHS ON RECORD

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Warmest	1916	1779	1938	Several	1833	1846	1808 1852	1779	1865	1921	1818 1938	1934	1834
	45 3	46 5	47 5	50 5	58 5	64 0	64 8	65 0	61 0	55 3	48 5	46 4	50 4
Coldest	1814	1855	1785	1837	1782	1823	1816	1912	1807	1817	1782	1878	1784
	25 6	28 9	33 5	39 9	46 5	52 9	55 3	54 5	48 7	42 6	35 0	30 0	44 8

Greek Civilisation and the Modern World.

By T. B. L. Webster.

There are two different approaches to the study of Greek art and literature, which may be called, to borrow terminology from Aristotle, the contemplative and the practical. The contemplative approach rests on the belief that it is good to know about beautiful things of any age or place ; it also makes tacitly or aloud the assumption that such knowledge somehow feeds back into practical life, but primarily it regards the contemplation of beauty as an end in itself. For such a view ancient Greece derives its claim-to-study from such lines as Sappho's "As the sweet-apple blushes on the top bough, atop on the topmost bough, and the applepickers forgot it ; no, they did not forget it, but they could not reach it"—or from the exquisite line-drawings on Athenian white ground vases ; these are absolutely beautiful like the poetry of Yeats and the etchings of Picasso, and on this view need no further justification.

I am concerned to-day with the second approach, the practical, and that must be based chiefly on the political contribution of Greek thought. It can be shown historically that the rebirth and regrowth of democracy from the time of the Tudors till the present day has been assisted by the inspiration of ancient Greece. There is little doubt that we are now facing a major crisis of democracy. From the time of the Tudors the freedom of the individual has been the central belief of Western Europe and the driving force in Western European political, scientific, and social development. In the period between the wars the order founded on this belief collapsed over wide regions of Europe. The war was fought for the restoration of individual freedom, but a freedom restored by force of arms and weight of material cannot survive unless it finds a surer foundation in the inner conviction and explicit profession of its adherents. The new factor, which has become clear in the last twenty years with the rise of Nazi Germany, Fascist Italy, and Communist Russia, is the assault of the totalitarians on the inner citadel of democracy, the totalitarian claim to be the true democracy because equality of opportunity is assured in the totalitarian state. The ground, therefore, has changed and we fight to-day not so much for equality of opportunity, but for the freedom of the individual, the right of the individual to freedom of speech and action, the right of the amateur to criticise the expert, and the right of the

ordinary citizen to criticise and if need be to overthrow the Government. Since this view of political life was first discovered in Ancient Greece, the practical approach to Greek studies is to reconsider Greek political thought in order to discover how the freedom of the individual arose and to what problems its maintenance or suppression gave rise.

Such a study could be either historical or analytical, dealing with the problems that affect us to-day. I propose to combine the two approaches in an attempt to see the problems in their historical context. In the earliest Greek literature that survives, the *Iliad* and the *Odyssey*, which probably took on their final shape not later than the beginning of the eighth century B.C., in a small feudal world of kings, princes and warriors, there are already signs of the future development in Homer's interest in psychology and in his portrait of Thersites. The fact that Homer finds it necessary to account for a sudden change in Achilles' conduct by sending Athena from Olympus to make up his mind for him shows that the Greeks were already interested in the factors that make up the individual personality, and had already started on the road which led to the character drawing of fifth century tragedy and so to Plato, Aristotle, and the New Comedy, until the Stoics asserted that the reason in the human soul, which governs the individual's life, was one with the reason that governs the universe and that all that matters is the motive and not the act. The answer to the question of the individual's responsibility for his acts is bound up with the question of democracy if, as I maintain, the freedom of the individual is democracy's central belief. It is probably therefore something more than a coincidence that the first clear identification of goodness with purity of motive occurs in a poem of Simonides written at the time of the refounding of the Athenian democracy at the end of the sixth century when the poet was undoubtedly deeply influenced by Athenian democratic thought: "I have made a discovery, and I will tell you. I commend and love all, whoever of his own free will does nothing base".

According to modern scholars the words for conscience and duty were first invented by the Stoics in the late fourth or early third century B.C., but the idea was present more than a hundred years before, as can be seen from the portraits of two conscientious objectors drawn by Sophocles and Plato. The main problem of

Sophocles' *Antigone* is the clash between the individual, Antigone, and the State represented by its king, Creon, and the play may be regarded as symbolical of the clashes between the aristocratic opposition and Pericles in the forties of the fifth century B.C. Creon has decreed that the body of Polynices, Antigone's brother, must be left unburied ; Antigone decides, nevertheless, to bury it (translated by C. M. Bowra) :

" It was not Zeus, I think, made this decree,
Nor Justice, dweller with the Gods below,
Who made appointment of such laws to men.
Nor did I think your mortal edicts were so strong
That any mortal man should override
The Gods' unwritten and undying laws.
Their life is not to-day and yesterday
But always, and none knoweth whence they came.
I would not pay the price before the Gods
Of breaking these for fear of any man."

The appeal over the decrees of the State to the unwritten laws of the Gods is the appeal to conscience. The mysterious voice which warned Socrates is also something like what we mean by conscience, and Socrates, as represented in Plato's *Apology*, like Antigone, preferred the dictates of conscience to the dictates of State. " I never held public office but I was a member of the Council, and my tribe Antiochis was performing the Council's business when you decided to condemn the whole body of ten generals who failed to pick up the dead after the sea battle—which was contrary to law, as you later decided. Then I alone of the presidents opposed your acting illegally and voted against you. The orators were ready to impeach and arrest me, and you shouted approval, but I thought I ought rather to run the risk with law and justice on my side than to side with you in your unjust designs through fear of death or imprisonment." Here Socrates was acting in defiance of the State's momentarily expressed will, because like Antigone he obeyed a higher law. When he was condemned to death on an unjust charge and his friends offered to arrange for him to escape and live in exile, he pictured the laws of Athens visiting him in prison and interrogating him : " Do you think a city can exist in any stability if sentences passed have no validity, but can be upset by private individuals ? . . . If you escape . . . we shall be angry with you

while you live, and in the grave our brothers the laws of Hades will not receive you kindly, knowing that you tried to destroy us, too, as far as you could". This obedience to the State where only Socrates himself suffers from the State's injustice distinguishes his individualism from that of the Cynics who claimed to be his pupils but preferred to live as resident aliens so as to be free of all civic duties.

The temptation to live in an ivory tower was strong in the fourth century B.C., as we can see from Plato's account of the philosopher in his *Republic* and Aristotle's opposition of the contemplative and the practical life and later the Epicurean ideal of quietness. The later Stoics at least healed the breach, since we find in them the chief opponents of the Roman emperors. Socrates' combination of obedience to conscience against the State and obedience to the State to his own disadvantage was a rare and perfect thing, and sets an ideal which is as valid for us as for him. It is difficult to put its meaning into words which apply to our present-day life and education. I believe the essential to be a kind of double citizenship, that a man is a better citizen of an earthly kingdom because he is also the citizen of a heavenly kingdom : " Render unto Caesar, etc." But it is far too narrow to restrict the heavenly kingdom to the devotees of this or that religion ; it includes all the goods which Aristotle includes in the contemplative life, the things that are loved for themselves and for no practical purpose, the ultimate satisfactions of the individual man which give him independent and immutable standards enabling him to see the present mutable problem which he is asked to judge in its true perspective, and he can judge the better and decide even to his own practical disadvantage because his true kingdom is set somewhere else.

So far we have discussed the development of the concept of individuality in the ancient Greek world. We can now return to the State. Homer's portrait of Thersites is the earliest portrait of a popular opponent of the established Government. He was the ugliest man who came to Troy, " he knew many words in his heart, but they were all disorderly, for he strove with the kings ". When he criticised Agamemnon in the army assembly, Odysseus beat him into silence and the people cheered. The bias of the poet is clear, but he has nevertheless recorded the beginning of democratic opposition to the reigning princes. Kingship

which was the normal form of government in Homer's time, gave place to the rule of the landed aristocracy. In the seventh century the change-over in farming from corn and sheep to wine and oil and the growth of ancillary industries such as pottery gave prominence to a new merchant class, existing on slave labour, which threatened both the landed aristocracy and the smallholders, in Athens we know of a stage where the wealthy bought themselves into the aristocracy by acquiring the land of the smallholders, who became tenants of the land they had formerly owned and were frequently enslaved for debt For the first time there was a violent opposition of rich and poor, and Solon was called in to make a "new deal" in 594 B C

Looking back at sixth century democracy (and they speak sometimes of Solon, sometimes of Cleisthenes, and sometimes of both), the speakers of the fourth century, Plato, Isocrates, Demosthenes, and Aristotle, all regard it as the best constitution that Athens ever had For our present purpose, however unhistorical such a procedure may be, we may speak of a single form of sixth century democracy There are four chief elements in this form of democracy, the popular assembly or ecclesia, which passed laws and, like the juries of the law courts, was open to the whole citizen body, the council, which prepared the business for the assembly and later dealt with foreign affairs and finance—the citizen body elected a large list of candidates from which the necessary number were selected by lot, the magistrates, who were elected from the citizens of the two highest property classes, and the Areopagus, the council of ex-magistrates which had charge of the murder courts and a general watching brief over the constitution A strange institution which came in at the end of the century was the institution of ostracism, the assembly could vote that a prominent citizen should leave the country for ten years, retaining however his citizen rights and his property. In practice it was not, I think, so much a method of getting rid of a man who was too big for democracy, and should according to Aristotle have been made a king, but a method of changing the city's policy not unlike a general election: the ostracism of the aristocratic leader Cimon in 462 B.C. heralded the democratic policy of Pericles. But the chief merit which the fourth century thinkers saw in the sixth century democracy was its stability, which they attributed to the respect for law or the

modesty (*sophrosyne*) of the citizens; Plato sees the cause in the "rule of respect", Isocrates in the educative functions of the Areopagus, and Aristotle, more realistically, in the fact that hard-working farmers had little time to attend the assembly. The theory of this early democracy was in fact probably formed earlier than the fourth century, since we find it already in Thucydides and what seems to be an echo of it even earlier in Sophocles' *Ajax*, which was produced in the 40's of the fifth century. As phrased by Thucydides, the theory is that "the rich are the best guardians of money, the intelligent would give the best counsel, and the many would give the best judgment when they had heard". It is possible that Protagoras was the author of this theory, since in the dialogue which Plato names after him Plato makes him maintain that the Athenians "have good reason for admitting a smith's or a cobbler's counsel in public affairs", because they have the fundamental virtues of Justice and Modesty (*sophrosyne*). The theory has echoes in Isocrates and also in Aristotle, when he says that "the many, of whom each individual is but an ordinary person, when they meet together, may very likely be better than the few good, if regarded not individually but collectively, just as a feast to which many contribute is better than a dinner provided out of a single purse. For each individual out of the many has a share of virtue and prudence, and when they meet together their moral and intellectual power works rather on the analogy of one man with many feet and many hands and many senses".

Before we consider the implications of this theory of democracy we must consider what happened during the fifth century and the early fourth century to make the thinkers of the mid-fourth century with one accord look back to the golden age of Solon and Cleisthenes, and it is somewhat startling to find that the age of Pericles which we have all been taught to admire is for them if not the extreme of decay, at least an advanced stage of decline. Pericles for us is the Pericles of the Funeral Speech in the second book of Thucydides, the Pericles who stated the ideal of democracy in words that have never been forgotten: "We are called a democracy because the administration is in the hands of the many and not of the few. But while the law secures equal justice to all alike in their private disputes, the claim of excellence is also recognised; and when a citizen is in

any way distinguished he is preferred to the public service, not as a matter of privilege but as the reward of merit . . . we are prevented from doing wrong by respect for authority and for the laws, having an especial regard to those which are ordained for the protection of the injured as well as to those unwritten laws which bring upon the transgressor acknowledged shame. . . . W alone regard a man who takes no interest in public affairs not as a harmless but as a useless character ; and if few of us are originators we are all sound judges of a policy. . . . To sum up, I say that Athens is the school of Hellas and that the individual Athenian in his own person seems to have the power of adapting himself to the most varied forms of action with the utmost versatility and grace ". For us Pericles had a dream of democracy which men have ever since been trying to realise. The writers of the middle and second half of the fourth century saw him as the author of certain tendencies in democracy which lost the Athenians the Peloponnesian war and led to further continuing disasters in the fourth century. The facts are undeniable, and they saw three main causes, the payment of public services, the venality of politicians, and the " ethics of grab ". Periclean Athens was an imperial city with a greatly increased population and imperial tribute to spend. Pericles introduced payment foı State services including the Council and the Lawcourts ; at the same time the property qualification for the higher offices had been reduced and more of them were chosen by lot instead of election. The result was a great increase in the number of poor citizens able to take part in State business and the development of a technique of mob oratory to capture their votes ; of this we have fifth century evidence in the comedies of Aristophanes and Plato defines the art of the public orator as flattery like cosmetics and cooking. The further result was the embitterment of the wealthy and the aristocrats, who adopted the sophistic theory that justice is the expediency of the stronger or the " ethics of grab"; the frightful results were seen in the Tyranny of the Thirty after the fall of Athens in 404 B.C. From the point of view of the Athenian policy as a whole the worst feature of the full-blown democracy was its inability to pursue any course consistently. Stability of external policy and of internal relations made the earlier democracy of Cleisthenes and Solon seem golden by comparison.

Pericles had foreseen the danger and said : " We are prevented from doing wrong by respect for authority and for the laws " ; it is along these lines that the fourth century thinkers seek a solution. Plato's attempt to find a philosopher king and Isocrates' search for a generalissimo to lead a united Greece against Persia we can, I think, regard as irrelevant to our subject, although in fact they foreshadow the conquests of Alexander and the shape of the Hellenistic age. Far more important is their essential answer that the need is education. Plato's education is the more fundamental and revolutionary. He starts with the child and rewrites Greek myths so that the early " arts " education of children may train them in the virtues of piety, courage, modesty and justice, and that they may be " led from childhood unknowingly into likeness and friendship and harmony with fair reason". At the other end of the scale he prescribes for the philosophers who are to govern his ideal State a training in pure mathematics, leading to pure philosophy. It is the first assertion that the best training for practical political life for certain carefully selected individuals is a training in pure thought ; it is the charter of the university of to-day as the training ground for politicians and administrators. Isocrates has the more limited aim of training good speakers for the Athenian assembly, and his education is partly in the technique of public speaking and partly in the history of Greece as a source of commentary on the present ; in modern terms, a wider class of prospective politicians could well be trained in modern history.

The very acute criticism of Aristotle, who is the most detached and scientific of the fourth century thinkers, raises questions of universal reference, although his answers are coloured by his time and place. First, the prototype of the good State is the family, and in the family the father is ruling equals for their good; therefore the object of the government of the State must be the common good (the " ethics of grab " is demolished at a blow). The specific characteristic of a citizen as a citizen is to rule and be ruled (often, to be ruled when he is young and to rule when he is older) ; therefore citizenship should be restricted to those who are capable of this. Aristotle excludes artisans, tradesmen, and farmers because they have no time. Our answer would be that with modern methods of production we can give them as much leisure as the Athenian landowner or middle-class

business man Leisure Aristotle regards as essential because absence of leisure precludes not only good political activity but also the contemplative life (as described above), which is man's truest happiness The State must be large enough to be self-supporting, but must not be too large "to judge in the law-courts and to distribute offices according to worth the citizens must know each other's characters" Here again Aristotle could not foresee the uses of printing, wireless, and television as a means of "knowing each other's characters" "Those States are likely to be well administered in which the middle class is large and larger if possible than both the other classes or at any rate than either singly", this would avoid one of the major evils of Greek politics, the division of the city into two camps of rich and poor

The historical importance of the fourth century, of Plato, Isocrates, and Aristotle, is that they made the Hellenistic age possible Alexander could have conquered the world without Aristotle, but the conquest of the then known world by Greek ideas and its preparation thereby for Christianity, would have been impossible unless Alexander, his successors and the host of colonists who followed him had not imbibed the teaching of the Greek fourth century thinkers For our present purpose, however, it is more important to try and record the basic ideas which some five hundred years of city state life, including a final hundred years of introspection and self-criticism, bequeathed to the world

1 The object of the State is the common good of the citizens, this means giving them the opportunities for happiness, for pursuing those things which they regard as good in themselves—the contemplative life Aristotle would restrict citizenship to those who have sufficient means for leisure, we should say that it is the duty of the State so to regulate incomes and hours of work that all citizens have such means

2 The function of a citizen is to be a member of a State, i e not only to be ruled, but also to hold some sort of office, the minimum is to vote at municipal and general elections and to sit on a jury

3. Offices must be awarded according to merit, which includes technical skill, but the final judge of policy is the citizen body, and the amateur judgment serves as a corrective to the possibly blinkered view of the expert.

4. If such a constitution is to work and not to founder on instability, mob oratory and class war, further requisites are the education of the ordinary citizen, the education of the politician and administrator, and the avoidance of excessive inequalities of wealth. To take these in reverse order, the last is the clearest means of avoiding the class war in modern as in ancient societies, and can be effected by income tax, supertax and similar machinery ; it does, however, raise the further problem of the outstanding citizen. No State can afford to lose its outstanding citizens, and therefore a certain room must be left for their development ; the really powerful natures are far too valuable to be excluded by taxation, ostracism, or any other means. This, I think, is the feeling underlying the phrase : "The rich would be the best guardians of money" in the formula for the balanced democracy and in Aristotle's assertion that if there is a pre-eminent citizen he must if necessary be made king ; in one sense it means that extraordinary powers are sometimes justified.

Not much more need be said about the education of the politicians ; Plato and Isocrates have given very suggestive hints on the training of two different kinds of political experts. An equally important problem is the training of the ordinary citizen because he has the final decision on policy, and as Demosthenes said, politicians do not make the people good or bad, but they make the politicians whichever they like. For this kind of education, too, Plato has laid down the lines in the *Republic* ; it is primarily an education in morals in the early stages, and the ordinary citizen does not get beyond the early stages. The ideal to be aimed at has been set by Socrates, and the good citizen must have other values which mean more to him than success or advantage in the world of the State. He is the better citizen because his judgment is so informed, and the end of the State is to enable its citizens to pursue such other values.

T. B. L. WEBSTER.

The Work of the Department of Scientific and Industrial Research.

By Sir EDWARD APPLETON, G.B.E., K.C.B., F.R.S.

The Department of Scientific and Industrial Research has rather a long name, but the initials D.S.I.R. come fairly easily off the tongue, and I hope they are so well known that it is not necessary to explain them.

People often ask me the simple question : " What is D.S.I.R., and what does it do ? " My answer naturally depends on the time they are prepared to listen. If I feel I have to be brief I say this : The D.S.I.R. is a Department of State for which the Second Minister of the Crown, the Lord President, is responsible to Parliament. It does three things :

(*a*) it carries out research itself and sets a good example in its standard ;

(*b*) it encourages Industry to do research ;

(*c*) it encourages the supply of research workers and encourages research in Universities by way of grants.

But here I can describe D.S.I.R. and its work in more detail. And the first thing I want to say about D.S.I.R. is that it uses science, and encourages science outside its own borders, *because* science gives practical results—sooner or later.

I imagine that many of you must be aware of the rumblings of a rather violent—and noisy—controversy concerning the mission of science which is taking place to-day. This controversy is being waged between extremists, as most controversies are. At one extreme you have the group of individuals who claim that science should be pursued simply for its own sake, with no thought of any practical objective. A smaller section of this group go even further, and rate the prestige of a particular piece of scientific work particularly high when it would appear that its results are unlikely to be of the slightest practical use to anyone. The extremists in the other camp claim, in reply, that science is simply a social servant, and that it should be pursued solely for practical ends. They think that the balance sheet of scientific enquiry must be drawn solely in terms of social utility.

I certainly do not propose to try to take sides in this controversy. My own position is a very simple one in that I think *both* sides are wrong. I do not believe that you can make a valid distinction between what is called pure and applied scientific research and rate one or the other a loftier form of human

activity. The field of science seems to me essentially one, in that whatever may be the particular objective, the same scientific method—the same combinations of observation, theory and experiment—is universally used. Nor do I feel that the scientific worker—at any rate, judging from my own experience—has any different mental attitude, or feels any different enthusiasm, when at work on a fundamental problem or on an applied problem. In fact, I am quite sure that one very often cannot say whether a problem is one in pure or in applied science. I have devoted many years to the study of the upper atmosphere. You could say that I was using radio waves as a tool to explore the distribution of electricity in the higher atmosphere—a purely scientific problem you might call it—or you could say that I was studying how the ionised layers of the upper atmosphere influenced the travel of electric waves in radio-communication—an applied problem. I do not pretend to decide. But it was the same work whichever way you choose to look at it.

Now I want to admit here and now that the objects of D.S.I.R. are avowedly utilitarian. Its main aim is to advance scientific knowledge for the general benefit of the community and the benefit of industry. But the growth of science is like the growth of a tree. If you are interested in the fruit of a tree you must be sure that there is healthy growth in the roots. And we find that our work in the Department, although *objective* in general character, is only sustained in fruitfulness if it is accompanied by an adequate growth of new knowledge resulting from what is often called fundamental research.

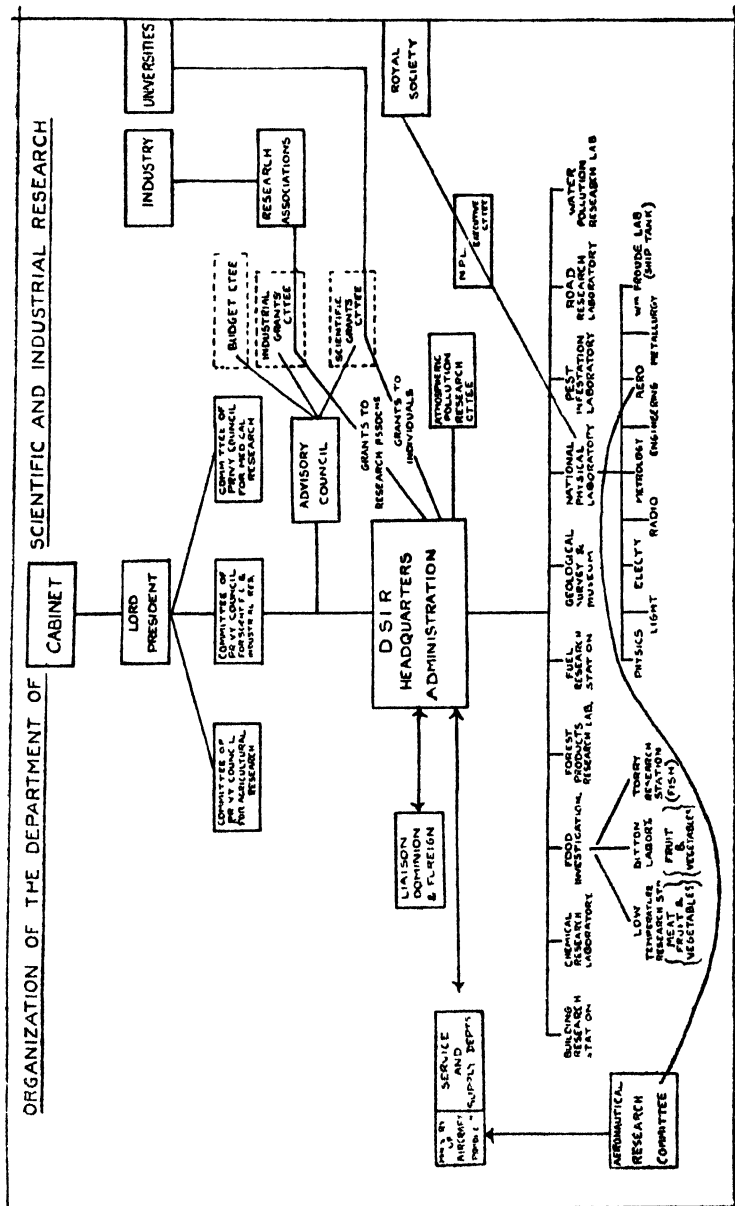
Now during the present war many people appeared to have heard for the first time of the work of Government scientists. Indeed some people seem to think that scientists have been mobilized for the first time to work on problems of national importance. It is quite true that very many scientific workers from the universities and industry have placed their services at the disposal of Government Departments during the war, and so have increased the volume of scientific effort and achievement. But what I want to emphasize is that the main framework of the Government scientific organisation was in existence well before the war. There have been extensions it is true, but the chief result of the war has been the expansion of the staffs and activities of *existing* research establishments.

I expect that many of you missed seeing a rather unobtrusive White Paper* recently published by the Government, and issued to Parliament, which describes in a very condensed way the structure of the scientific organisations of Government. Its contents, so far as D.S.I.R. is concerned, are summarised in diagrammatic form in Figure 1.

Now you may well ask the question : " Why has Government instituted these scientific establishments to conduct research in these particular fields? " The answer is that it is because Government is vitally concerned with the applications of science in the interests of the well-being and prosperity of the community. We must note the change in the function of modern Government in becoming less negative and more positive. As Graham Wallas so aptly put it, a modern Government " has come to be engaged not merely in preventing wrong things from being done, but in bringing it about that right things shall be done." In other words, modern Government has undertaken the direct responsibility of the active improvement of the welfare of the community, and certain aspects of such improvements need scientific knowledge. Some of the scientific knowledge required is available, and only needs interpretation and application, and some of it has to be acquired by scientific research. To a steadily increasing extent we can, I think, say that science is being used as the basis of the formulation of Government policy.

It has been announced that the Government accepts responsibility in providing work, food and homes for all of us. These tasks are in addition to those of keeping the nation healthy, and safe from aggression. If you think about these five things, work, food, homes, health and safety, you will understand the more readily the features of the pattern of Government scientific research. D.S.I.R. is concerned with some of these five objectives. It tries to encourage research and the application of scientific knowledge in industry, because we believe that only in that way can the industry of the country flourish in a competitive world and so provide adequate employment. The people of this country live in houses, travel on roads, burn fuel, drink water, eat food and so on. We in the Department conduct research on buildings, roads, fuel, water and the storing and processing of food. Agricultural

* Cmd. 6514 : H.M.S.O. 1944, 1d.


ORGANIZATION OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH
CABINET
LORD PRESIDENT
UNIVERSITIES
INDUSTRY
RESEARCH ASSOCIATIONS
ROYAL SOCIETY
BUDGET CTEE
INDUSTRIAL GRANTS CTTEE
SCIENTIFIC GRANTS CTTEE
N P L EXECUTIVE CTTEE
COMMITTEE OF PRIVY COUNCIL FOR MEDICAL RESEARCH
COMMITTEE OF PRIVY COUNCIL FOR AGRICULTURAL RESEARCH
ADVISORY COUNCIL
GRANTS TO RESEARCH ASSOC'NS
GRANTS TO INDIVIDUALS
ATMOSPHERIC POLLUTION RESEARCH CTTEE
D S I R HEADQUARTERS ADMINISTRATION
LIAISON DOMINION & FOREIGN
SERVICE AND SUPPLY DEPTS
AERONAUTICAL RESEARCH COMMITTEE
BUILDING RESEARCH STATION
CHEMICAL RESEARCH LABORATORY
FOOD INVESTIGATION
FOREST PRODUCTS RESEARCH LAB.
FUEL RESEARCH STATION
GEOLOGICAL SURVEY & MUSEUM
NATIONAL PHYSICAL LABORATORY
PEST INFESTATION LABORATORY
ROAD RESEARCH LABORATORY
WATER POLLUTION RESEARCH LAB
LOW TEMPERATURE RESEARCH STN (MEAT, FRUIT & VEGETABLES)
DITTON LABORY (FRUIT & VEGETABLES)
TORRY RESEARCH STATION (FISH)
PHYSICS
LIGHT
ELECT'Y
RADIO
METROLOGY
ENGINEERING
AERO
METALLURGY
Wm FROUDE LAB (SHIP TANK)

(Fig 1)

and medical research are not our province, but are the responsibilities of our sister organisations, the Agricultural and Medical Research Councils, in collaboration with the Ministries of Agriculture and Health. During the war D.S.I.R. has played a part in the fifth objective, namely, in trying to keep the nation safe.

Now, as I said earlier, some of the Government scientific organisations have been in existence for quite a long time. D.S.I.R. is now thirty years old, for it was established in the middle of the last war. It is worth noting that the Government founded it as an expression of forward-looking policy, for the Department was created *not* to conduct research in the interests of the war effort, but to be instrumental in serving the nation, and particularly the industries of the nation, when peace returned. By the original Order in Council which established the Ministerial Committee under the Lord President of the Council, an Advisory Council to the responsible Minister was also constituted. This was, I think, a very early example of the use of a body of independent members *outside* Government accepted as advisers on policy for implementation *inside* Government. The Advisory Council is a body of experts, which advises the Lord President on the scientific policy to be followed, and upon all important matters falling within the scope of the Department. Its membership is composed partly of eminent men of science and partly of industrialists, particularly those prominently associated with industrial research. Quite recently two representatives of Labour have been added to it.

Now, as its name implies, the Council is advisory and not executive, and the great influence which it exercises derives largely from the fact that its members are selected by the Lord President as individuals, and are not appointed as representatives of particular interests or organisations. The present chairman of the Council is Lord Riverdale.

Now what exactly does the Department do in carrying out its stated duties?

(1) First, it does research in its own stations. This research is conducted for the benefit of the community as a whole and to meet the requirements of other Government Departments, e.g., Ministry of Fuel and Power, Ministry of Works, Home Office, etc.

(2) Second, it tries to encourage research and the application of scientific knowledge in industry.

(3) Thirdly, it encourages, as a main source of new knowledge, fundamental research at universities and like institutions, and the maintenance of an adequate supply of trained research workers for laboratories of all kinds.

During its history the Department has established, or assumed responsibility for, ten main research establishments, some of which have further regional or other out-stations. It is of special interest that both the oldest and the largest of these stations actually were in existence before the Department came into being.

The Geological Survey of Great Britain, which not many years ago celebrated its centenary, is our oldest scientific establishment. Indeed it is the oldest Geological Survey in the world. Its work covers the scientific study of the geology of the country, and the collection of exhibits illustrating geological formations and rocks, minerals and fossils from Great Britain and other parts of the world. The advice of the Survey, based on these data, which are continually being augmented, has been in continual demand by Government and Industry on the distribution of mineral deposits of all kinds, coal, iron, non-ferrous metals and on water supply problems. The Geological Survey has a branch in Manchester which works in close and friendly collaboration with the University. The Survey is almost invariably consulted before any important civil engineering work of any kind is begun, and during the war its assistance has been of the greatest importance in finding home sources of minerals essential for war production, minerals which would otherwise have had to be imported. Two examples of its work, taken almost at random from the records of the Survey, will serve to show the close relationship between geological science and its application in everyday affairs. In providing a water supply for an important town a series of borings had been made, but had yielded no adequate results. It was believed that the water-boring clays had been reached and that further boring would be futile. Before abandoning the scheme, however, the Survey was called in, and as a result it deduced from the presence of certain fossils—the alleged playthings of the academic mind—in the bore that water-bearing levels had not in fact been reached

and that the deepening of the bore should tap them. The engineers therefore persevered, with the result that a magnificent supply was obtained.

Take another example ; it is not long ago since we needed sand for sandbags in large quantities in the London area. The Survey from its detailed knowledge of this area indicated at once where the sand could be found near the surface. I understand that transport costs of getting on to £200,000 were saved in this way.

Our largest establishment is the National Physical Laboratory at Teddington, which employs a staff of well over 1,000. Its main function is research into methods of measurement upon which apparatus for research and for the control of industrial processes must ultimately be based. The laboratory is responsible for the maintenance of national standards of mass, length, and time ; for the various electrical units, and for the accurate determination of the physical constants of materials and for the study of the properties of engineering materials and equipment. In its various divisions, tests and calibrations are also carried out on apparatus such as volumetric glassware, clocks and watches, thermometers, physical balances and optical instruments such as sextants, binoculars, etc. Under modern methods of production the gauges used in works for the construction of such things as motor vehicles or aircraft have for some purposes to be correct to one ten-thousandth of an inch. In checking these, sub-standards have to be available correct to one hundred-thousandth of an inch and to calibrate these the laboratory must be in a position to measure accurately to within a millionth of an inch. For this purpose apparatus has been developed for measuring length in terms of the wavelength of light.

Under the Department's Radio Research Board the radio division of the laboratory has been responsible for a very complete study of the propagation of radio waves at all frequencies and for the investigation of the electrical state of the upper atmosphere and its effect on radio communication. In its application this work established the technique employed in the development of radiolocation, and has enabled the most suitable frequencies for communication between different points at different seasons of the year to be forecast with considerable accuracy.

In the tanks of the ship division, which are waterways several hundred feet long, tests on models of every variety of marine craft can be carried out and from these tests the performance of the finished vessel accurately deduced. The reliance of British shipbuilders on this work is indicated by the fact that ove 80 per cent of new mercantile construction started in this country in the years before the war was based on "tank" tests carried out in the laboratory. It is estimated that continuous research carried out in the ship division over the last thirty years on the resistance to motion of ships has saved the shipowners about £1,000,000 per year in fuel consumption alone.

The laboratory is always ready to place its knowledge at the disposal of firms or associations and to carry out special investigations on their behalf, provided staff and equipment are available. During the war its energies have naturally been centred upon war-work, but the consideration of post-war developments is far advanced. One such development is the establishment of a Mathematical and Statistical Division which will be available for consultation by workers in other Government Departments, universities and industry. It will provide computing services for them, undertake research into new statistical methods, and their application in various problems, and the design and development of new computing machines.

One of the oldest of our eight other research establishments is the Fuel Research Station at Greenwich. Nowadays it goes without saying that the efficient use of fuel is of supreme importance in every industry; while coal, which it should be remembered is now owned by the State, is our greatest raw material asset. The Fuel Research Station was established as a national research centre for the study of fuel problems. Its work has included investigations on the carbonisation of coal at high and low temperatures to improve the yield of gas and of smokeless and liquid fuels; on hydrogenation and other processes for the production of fuel oils from coal; and fundamental work on the chemical constitution of coal itself. In addition, coal cleaning, i.e., the removal of non-combustible dirt from the coal as it comes up from the pit, and other methods of preparing coal for the market have been studied. Work has also been carried out on the storage of coal, the design of gas producers and pulverised fuel burners.

A most important section of work at the present time is that of the National Coal Survey, an organisation which owes so much to the vision of the late Director of the Station, Dr. Sinnatt, and which is conducted at nine laboratories in the various coalfields with headquarters at the Fuel Research Station. When a seam is under survey, pillar sections extending from the floor to the roof are cut, and the various bands making it up are analysed by standard methods and the amounts of carbon, hydrogen, nitrogen, sulphur, volatile matter and ash determined Measurements are made of the heating or calorific value of the coal, its coking properties, and the fusion point of the ash, which indicate how much slag will be produced when the coal is burnt in a furnace. The amounts of impurities such as chlorine, arsenic and phosphorus present in the ash, which affect the value of the coal for various purposes, are also found. As a result the quality and the most suitable uses of the seam can be assessed. When necessary the small-scale work in the laboratory is supplemented by trials of the coal in the full-scale plant at the Fuel Research Station. With the data collected by the Survey it is now possible to predict with considerable accuracy the properties of the coal at places where it is not yet accessible.

The part of the Coal Survey which deals with the Lancashire and Cheshire coalfields is a rather special one. It is called the Lancashire and Cheshire Coal Research Association, and is situated in Park Street. Major Pilkington is the Chairman of the Association and Mr. Simpkin is the Officer-in-Charge. This Association was founded by the Lancashire and Cheshire coal owners largely owing to the efforts of Dr. Sinnatt, who was then on the staff of the College of Technology. When Dr. Sinnatt became a Director of Fuel Research in D.S.I.R. he organised the Survey to cover the whole country, and the Lancashire and Cheshire Coal Research Association agreed to work in collaboration with the new Survey, and has continued to do so ever since. The collaboration has been extremely successful, and the Association is an excellent example of industry meeting its own research requirements, but collaborating with the Government organisation to the benefit of both parties.

The Survey in conjunction with the Geological Survey is now collaborating with the Coal Commission and the Ministry of Fuel and Power in assessing the reserves of coal of various

types, and on problems connected with the production of open-cast coal. The data collected by the Survey are essential in the planning of future mining operations on lines such as those proposed in the recent report of the technical experts of the Ministry of Fuel and Power.

The need for national research into building problems surely required no justification. In 1921 the Department set up a Building Research Station to provide a national organisation for building research. Its programme covers the study of materials both traditional and new; the acoustics of buildings, the exclusion of noise, heating, lighting and ventilation, the exclusion of damp and other matters concerning the comfort and efficiency of buildings for all purposes. Before the war the Station began work on the study of foundations, generally comprised by the term "soil mechanics", which has now been extended to deal with problems met with in the cutting of embankments and of drainage cuts such as those in the Fen district. Apart from its programme of general research the Station provides technical assistance, in one form or another, to all engaged in the industry. Several thousand enquiries on building problems and requests for special investigations or tests, received from architects, builders or contractors, are dealt with each year. The Building Research Station is now studying new designs for houses for which purpose a number of experimental houses are being erected at the Station. These will be used for the examination of new ideas and the collection of data, particularly with regard to heating systems and their relation to house construction. The closest collaboration is being maintained with the Ministry of Works, the Ministry of Health, and the Ministry of Town and Country Planning. The first fruits of this appeared in the report of the Inter-Departmental Committee on House Construction, which is based largely on 20 years' work at the Building Research Station. In this Report it has been possible to set out for the first time in quantitative terms the desirable standards of house construction. This is a matter of great importance when novel forms of construction, not of a traditional character, are likely to be used on a considerable scale. The Report is the first of about a score, some of which have already appeared, to be issued by the Ministry of Works, on post-war building problems, dealing with such subjects as

plumbing, lighting, heating and ventilation, fire risks, etc. Another important step was the appointment of the Ministry of a Committee to prepare codes of practice for building operations covering the whole range of building construction. In the preparation of both the reports and the codes, the Building Research Station is giving its fullest technical assistance, and I feel I should stress this work as a particularly striking example of successful collaboration between D.S.I.R., a scientific Department, the Ministry of Works, an Executive Department, and industry in bringing together new scientific knowledge for the benefit of the whole community.

Now the Department's stations which I have described to you have been concerned with the problems in physical science. In our Food Investigation organisation we step into the realms of biological science, and so our interests overlap those of our sister organisations the Agricultural Research Council and the Medical Research Council. There are, however, very simple ways of defining our respective fields of research. In the question of food our work begins when the crop is cut, the beast is killed and the fish are caught. We deal in fact with the scientific study of problems of the transportation, preservation and processing of foodstuffs and the methods of maintaining the qualities of freshness until the food reaches the consumer. Problems of nutrition are in the province of the Medical Research Council.

As you will have seen from the diagram on the slide, our work on food is carried out at three research stations, the Low Temperature Research Station at Cambridge, the Torry Research Station at Aberdeen, and the Ditton Laboratory near Maidstone.

At the Low Temperature Research Station the fundamental causes of the decay of meat and bacon, and methods of slowing down the chemical processes taking place, and the growth of micro-organisms responsible for it have been studied. One result of this work has been a method of storage by which beef, which, as we know to our cost during the war, does not take kindly to being frozen, can be maintained in a chilled condition from 10 to 12 weeks, long enough for it to be transported from Australia or New Zealand.

The Torry Research Station was opened in 1929 to enable the results of fundamental research on the preservation of fish to be applied at an important fishing port. Here it has been

demonstrated that the time during which fish can be landed in first-rate condition can be extended from six to 12 or 14 days by the application of simple measures on board the trawler—a result of great importance in view of the time which the trawlers have to spend in reaching the fishing grounds. It has also been shown that by the process of "brine freezing" and storage at suitable low temperatures, fish can be kept in perfect condition from four to six months. This process can be applied both to white fish and to herring. Greatly improved designs of kilns have also been evolved for the kippering of herring, giving an improved product in less time and with less labour than with traditional designs of kiln.

Equally striking successes have been obtained in work on the storage of fruit and vegetables. One of the first successes in this field occurred in 1922 when unusually heavy losses amounting to as much as £250,000 were reported on Australian apples. The scientists of the Low Temperature Research Station were called in to advise. They recognised the trouble as being due to a disease known as "brown heart" which they had been studying, which appears first as brown spots which later spread through the flesh of the apple. They knew that this disease was produced by suffocation of the fruit by the carbon dioxide produced by the apples themselves. What had happened was that the year had been marked by particularly calm weather, and the usual ventilation of the holds in the ships had not been sufficient, so that the cargoes had been suffocated. With the steps to ventilate the holds which are now taken, losses of this character are entirely avoided.

The application of fundamental research on the physiology of fruit to its storage have been tried out on a commercial scale at the Ditton Laboratory, which is equipped with large-size cold stores in which storage conditions can be accurately controlled. One of these is an experimental chamber in which the conditions in a ship's hold in any part of the world can be reproduced. As a result of the work at the Ditton Laboratory an improved method of storing home-grown fruit known as Gas Storage, which depends on maintaining the correct percentages of carbon dioxide and air in the atmosphere of the store, has been developed. By this method Bramley Seedling apples can be kept in perfect condition for 12 months or more, and Cox's Orange Pippins preserved with their full flavour until well after Christmas.

During the war most of the work on cold storage has been in abeyance, and investigations have been directed, in collaboration with the Ministry of Food, mainly to the preservation of food by drying.

Time does not permit me even to summarise the work of our other establishments. They have, however, made striking contributions in their several fields—in the better utilisation of timber, the construction of roads in the treatment of water sewage and trade effluents, in the protection of stored products, especially grain, against insect attack, and in chemical research, notably the isolation of valuable chemicals from coal tar, and in the study of corrosion and its prevention.

So far I have described in a very general way the work which our D.S.I.R. establishments carry out. As the Prime Minister stressed in a recent broadcast, bigger production is essential at this time to the nation's recovery, and this requires well-planned industrial expansion. All our Stations, such as the Building Research Station and our Food Investigation Organisation, have a part to play in providing the scientific knowledge which must be the basis of real and permanent expansion. There are, however, three of our organisations which have a special part to play in this matter, particularly in the *planning* of any expansion schemes. Let me illustrate this, particularly from the point of view of the North-Western region.

Every factory requires power, and in this area it comes mainly from coal. Secondly, many factories require large supplies of water often possessing special properties. Then having used the water, it must be got rid of without causing further pollution of our rivers and streams or imposing an impossible fresh burden on our already over-burdened sewage plants. Let me take these three problems in turn. Firstly, as regards coal. A large colliery company in South Lancashire, which is developing one of their coalfields on modern lines, proposed to extract coal from virgin areas to the south of their present workings, and in driving a heading for this purpose the coal seam was lost against a fault. It sought the advice of the Manchester Office of the Geological Survey, as a result of which it was estimated that the fault through this and associated coal seams was 450 feet nearer the surface. It was thus found that a larger area than hitherto was supposed contained valuable coal seams within a workable depth.

In 1944 the Ministry of War Transport bored in North Stafford primarily for methane gas to a depth of 4,200 ft. The borehole proved many valuable coal seams which were identified by the Geological Survey and analysed by the Fuel Research Coal Survey Laboratories at Chester. The analyses indicated that first-class coking coal seams lay at 3,600 ft. and below. This class of coal is in short supply throughout the country. These are particular examples.

In co-operation with the Ministry of Fuel and Power the coal reserves of the Lancashire and Cheshire coalfields have been the subject of general investigation during recent months. After making deductions for coal, that for one reason or another is likely to be unworkable, it is estimated that the total coal reserves of the region is about 2,000 million tons for seams over 18 in. thick, lying within 3,600 ft. of the surface. This means that at the pre-war level of output these reserves should give a life of about 150 years. It is also believed that there are certain virgin areas just beyond the southern limits of the ordinary workings where there are reasonable expectations of additional reserves, though at considerable depth. These require to be checked by systematic exploration and by deep boring. These are rough estimates, and the aim eventually is to make a complete survey of the reserves based on a virtual re-mapping of the coalfield by the Geological Survey, taking account of the physical and chemical data collected by the coal survey.

I can illustrate the assistance the Water Pollution Research Laboratory is able to give to industry in disposing of water after it has been used by an example. An interesting and valuable piece of work on this subject was recently carried out on the disposal of waste liquors from milk depots and factories at Ellesmere. Milk has a polluting effect 300 times greater than the same amount of domestic sewage, so that the problem facing milk factories dealing with as much as 20,000 gallons of milk per day is no small one. The research scientists of the Water Pollution Research Laboratory tackled this problem in the true scientific manner. It was clear that if no milk was wasted there would be no question of disposal of waste liquors, so initial investigations were aimed at preventing or reducing waste, by increased draining of churns, by provision of efficient draining boards, by the separation and utilisation of by-products such as

whey and buttermilk. Not only was waste greatly reduced, but the products available for use were considerably increased. Thereby the profits of the firm were accordingly increased.

Yet there still remained much unavoidable waste carried away in large quantities of water. To deal with this the Water Pollution Research Laboratory devised a scheme of filtration in two filters in series, the flow being reversed as the first filter showed signs of becoming choked. The system took more than three years to devise, but it is not expensive, and the firms which have used these filters find that the extra cost is negligible.

Industrial Research.

Besides carrying out research for the Government and the community the main function of the Department is to encourage industry to appreciate the value of research, and once having established the demand for it, to take all possible steps to ensure that the demand is fulfilled. The Department's task has naturally been easier with those industries such as the electrical and modern chemical industry, which have grown directly from discoveries made in the laboratory. It is harder with the long-established traditional industries into which a scientist often entered as challenger of long-accepted custom. It is not surprising that to some managements he appeared as a positive nuisance. Gradually, however, it began to be realised that the application of scientific knowledge was the only means by which the impact of competition could be met. Although in the long run research pays tremendous dividends, these are seldom achieved immediately, and although the cost of laboratory research is comparatively small, its application often involves lengthy and expensive development, besides heavy outlay in the scrapping of out-of-date equipment. To a firm without considerable financial reserves, private research must often appear as a risky venture and beyond the means of small firms which make up a large percentage of British industry.

These difficulties are met to a great extent by the Co-operative Research Associations set up with the Department's help. Before the war 21 Associations or similar organisations were serving the following industries :

Iron and steel.	Boot and shoe.
Non-ferrous metals.	Cocoa, chocolate and confectionery.
Cast iron.	

Coal.
Electrical.
Cotton.
Silk and rayon.
Wool.
Linen.
Leather.
Welding and scientific instruments.
Flour milling.
Food processing.
Laundry.
Paint and varnish.
Pottery and refractories.
Printing.
Rubber.

Since the beginning of the war nine new Research Associations have been established for shipbuilding, gas, coke, internal combustion engines, paper, and several other industries. The total expenditure of the Associations has increased from £280,000 in 1934 to over half a million pounds in 1939, and it is expected to top the million figure this year. Several of the Associations command very considerable incomes. That of the Coal Utilization Research Association, for example, is over £200,000 per annum, while those of the Iron and Steel, Cotton and Electrical Industries are well over £100,000 per annum, and the Shipbuilding Research Association expects to start with an income near this figure. All the Associations are aiming at increasing their scale of working very considerably, and in many cases expect at least to double their income. This should go far to remove the chief criticism of the movement, namely, that the scale of working of many Associations was too small to permit them to be fully effective. With greater resources they will be able not only to embark on longer-range work, to which co-operative research is particularly adapted, but to improve their liaison services and other means for assisting their members in their day-to-day problems and in the application of the results of research.

It is not often possible to assess the results of research in cash values, but two examples of attempts made some years ago to do this may be of interest. In 1933 the Iron and Steel Research Council calculated that the industry was saving coke worth £390,000 per annum in the production of pig iron and coal worth £1,300,000 per annum in production of finished steel as a result of co-operative research. In the same year the Electrical Research Association calculated that as a result of research costing £80,000 their industry was saving at least £1,000,000 per annum. However successful co-operative research may be, it can never be generally expected, especially in

short-range research, to obtain results more quickly or to be more profitable than research carried out in a firm's own Research Department, with a staff in a position to appreciate the firm's problems to an extent impossible to any outside organisation. Even if a firm is too small to afford a complete Research Department of its own, it must at least employ some scientific staff if it is to get the full benefit from co-operative research, or indeed to use other facilities for obtaining scientific help to the best advantage. As you all no doubt are aware the Chancellor of the Exchequer has recently encouraged research in individual firms by promising substantial remission of taxation on research expenditure in the future.

Fundamental Research.

We in the Department are convinced that fundamental research is the life blood of industrial progress and that the discoveries which flow from it prompt the most spectacular advances in the material field. As my own teacher, Sir J. J. Thomson, once said : " Research in applied science leads to improvements, but research in pure science to revolutions ".

While we believe that for the scientific health of any research establishment of sufficient size it is essential that some more fundamental research should be carried out in it, we are of opinion that best conditions for most fundamental research problems are those of complete freedom in which scientific workers may follow any line whatever which attracts them. These conditions are most easily achieved in the Universities.

The responsibility for general provision for University research is that of the University Grants Committee, but we are not thereby precluded from assisting specific activities. Accordingly, the Department has assisted research in Universities and similar institutions by making grants to individual workers. Such assistance normally takes the form of provision for the employment of research assistants or for the acquisition of special apparatus. The grants are made on the recommendation of our Scientific Grants Committee, which is a committee of the Advisory Council, the main criterion being the " timeliness and promise " of the work proposed. The Department has also made arrangements for assisting work on specific items and on the recommendation of our Boards or Committee for items of work on their programme to be carried out extra-murally. In fact,

my own work at Cambridge on the study of radio propagation was assisted on the advice of the Radio Research Board. Again, the Department contributed to work at Cambridge on the production of intense magnetic fields and to the provision of large-scale plant for the production of liquid hydrogen. Other examples of work carried out on behalf of the Department are investigations into chemical reactions at high temperatures, on the chemical constitution of coal and the study of fats and oils in relation to food processing.

A third way in which the Department is brought into close contact with Universities is in the scheme of maintenance allowances for post-graduate students, which allows them to be trained in the methods of research. On this scheme young graduates work under the direction of a suitable supervisor for perhaps two years on a problem usually selected by him. The aim of the scheme is not to turn out a specialist in some branch of research, but to provide the trainee with a real understanding of the scientific method of attack and to give him the degree of self-confidence necessary for the successful research worker.

War Work.

During the war the whole resources of the Department have naturally been devoted to war work on behalf of the Services for the Supply Departments. Much of this work cannot yet be described for security reasons, but reference can be made to some of the Department's activities. In collaboration with the Ministry of Home Security, the Building Research Station and the Road Research Laboratory have applied their knowledge of building materials, and in particular, of concrete, to the study of bomb damage and the design of air-raid shelters. When we passed from the defensive to the offensive the Road Research Laboratory played an important part by studying methods for destroying and in the design of bombs for special purposes. The plans for the famous air assault on the Ruhr Dams were first worked out in models in this laboratory. At the Building Research Station the study made of the effect of enemy incendiary bombs on our buildings was adapted to the study of the effect of Allied bombs on enemy methods of construction, models of which were put up at the Building Research Station. In this sphere also the Chemical Research Laboratory carried out important work on the production of foams for fighting oil fires.

More nearly in its own field the Road Research Laboratory has made extremely valuable contributions to the design of runways for airfields, particularly for producing and rapidly laying temporary runways in forward areas. The Fuel Research Station successfully investigated methods for treating fuel for flame-throwers. The Station also produced a simple and effective means for preventing the emission of smoke by ships at sea, based on simple modification to the doors of marine boilers. This work should have important peace-time applications to land boilers, both in improving the efficiency of combustion and in preventing smoke pollution. The help of all the Divisions of the National Physical Laboratory has been sought on many problems. For example, models of assault craft of all descriptions have been tested in the tanks of the Ship Division, including models of parts of the Mulberry Harbours.

The advice of the Water Pollution Research Laboratory was sought in the treatment of waste waters from Government factories, and the Laboratory also succeeded in producing by a chemical means satisfactory materials for converting sea water into drinking water by equipment which could be used in the rubber dinghies employed by airmen forced into the sea. The Forest Products Research Laboratory has co-operated closely with the Ministry of Aircraft Production in the study of plywood and adhesives used in the construction of wooden aircraft. On the food front reference has been made to the important part played by the Department in the study of dehydration and other problems. The work carried out at the Chemical Research Laboratory on the production of food yeast and its possibilities in providing cheaply and rapidly a supply of proteins enriched with vitamins for under-nourished populations has recently been described to the Society.

The Research Associations have also made important contributions, of which the following are merely examples. Cotton Research Association has produced a waterproof cotton cloth the fibres in which are twisted in such a manner that they swell immediately when they come into contact with moisture and so block up the interstices of the cloth and make it water-resistant without any other waterproofing treatment whatever. These cloths, while they are impermeable to water, allow the air to pass through them. They are now being produced by a section of the industry. A hose-pipe has been made from them which

will stand up to the Home Office tests, and garment cloths are being made for the clothing of airmen who may be immersed in sea water. This is an invention which should obviously have a great future after the war. The processes developed by the Wool Research Association for preventing the felting and shrinking of woollen goods have been employed by the Army for the production of underclothes and socks for the troops with excellent results. The Laundry Research Association has advised on field laundries, and the best means of washing without, or with very little, soap. This Association has devised a method of treating blankets with oil which has done much to reduce cross-infection in hospital wards. The Paint Research Association has done valuable work in the improvement of camouflage paints.

The Future.

So much for what the Department is, and has done in the past. But what about the future? We are not satisfied, and are now busily engaged in examining in close detail how our work should be adapted or re-orientated or expanded to meet post-war needs. Our Advisory Council, for example, has already instituted enquiries into the provision, in this country, for research into mechanical and civil engineering. Another enquiry is also being made into the probable requirements of industry after the war for routine testing and how these can best be met. We are busy building up a strong Intelligence and Information Division in our Headquarters whose task will be to assist those who seek our help on the best means of attacking their research problem. The same Division will seek to ensure that opportunities for applying new knowledge are not lost.

We believe the main structure of our organisation is sound, and will permit us to carry out the programmes that are before us. We do not intend to ask for money, and then think out ways of spending it. The subject of scientific research is to-day receiving much popular—I might almost say clamorous—support. Unfortunately, the uninformed think only in terms of money, as if the provision of money for research, or indeed the mere spending of money on research, is all that is required. The wise identification of problems for research and the availability of good men with ideas come first. I firmly believe that financial support for research will be forthcoming if the problems, men and ideas are already there.

The Relative Merits of Ground Limestone and Quicklime for Agriculture.

By H. FRANKLAND TAYLOR, F.R.I.C.

For some years prior to the war it had been considered that the general fertility of the soil of this country was in danger of deteriorating from lack of lime; and fairly recent independent estimates have placed the lime requirements of our soil at about 20 million tons.[1]

In 1937 the Agriculture Act was passed, whereby farmers could obtain lime at half its cost delivered to their farms, the Government paying the difference. It will be seen, therefore, that there is general agreement that efficient liming of the soil is of vital importance.

The important question whether the oxide, hydroxide, or carbonate of calcium (i.e. quicklime, slaked lime, or ground limestone or chalk) is the best for agricultural purposes is apparently still unsettled, for even authoritative literature is ambiguous in this connection, all three forms are subsidised by the State in a similar manner, and large quantities of both quicklime and ground limestone are used by the farmers. Pre-slaked lime is too expensive for agriculture, but it is often recommended for horticultural purposes and for use in the garden.

As regards the chemical properties of these two forms of lime—it is now generally admitted that there is little if anything to choose between them. The Ministry of Agriculture bulletin on the use of lime in Agriculture, for example, states that ground limestone or ground chalk can nearly always be relied on to give as good and as quick results as burnt lime, provided equivalent dressings are given; 35 cwt. ground limestone being stated to be required to replace 20 cwt. ground quicklime. When considering the chemical properties it should be remembered that quicklime, or slaked lime, will become converted to the carbonate, i.e. to the same composition as limestone, at least on the surface of the particles very shortly after it has been spread over the soil—certainly long before it has had a chance to be dissolved and washed into the soil to an appreciable extent.

(Since this paper was read the author has shown by experiment that slaked lime exposed on the soil out of doors in a layer one-eighth of an inch in thickness became carbonated to the extent of 75-80 % in 5 days. It may be assumed that thinner layers would carbonate more quickly and that the surfaces of the particles would be carbonated in a much shorter time.)

Thus shortly after the lime has been spread it has become in effect chemically almost identical with limestone.

The aspect to which it is particularly desired to draw attention is the physical state in which lime is commonly applied to the soil, an aspect which it is suggested has been very much neglected although the facts are quite well known. In order to appreciate the importance of this aspect it is necessary to consider the very slight solubility of lime; for slaked lime the solubility is 0·16 %, or ¼ oz. per gallon of water. A common dressing is 1 ton per acre, equivalent to 8 oz. per square yd. 8 oz. lime would require 32 gallons of water to dissolve it, if it remained as slaked lime. But as it quickly becomes carbonated when spread on the soil it will require much more water than this; calcium carbonate has only about one-twentieth the solubility of quicklime, hence theoretically 640 gallons of water would be required a few days after it had been distributed. Also with only ½ lb. of lime on each square yd. it will be appreciated that unless the lime is very finely powdered it will not completely cover the surface, and so much of the rain will sink into the ground without touching any lime. From these considerations it is obvious that it is only by actual surface contact with the soil and the acidic bodies in the soil that the lime can dissolve and do its work in a reasonable time. The rate of reaction of the lime with the acidic bodies in the soil will therefore be more or less proportional to the surface area of the particles of the lime. Thus it is essential to have the lime in a very fine state of subdivision for two reasons:

(1) In order that it can be distributed as evenly as possible over the soil, and (2) in order that when it becomes mixed with the soil there will be as large a surface as possible in contact with the soil. Fine subdivision is of vital importance in any sparingly soluble product applied to the soil. This is well known and is fully appreciated with fertilisers such as basic slag and cyanamide, which are sold as impalpable powders, but with

lime—one of the most important aids to soil fertility—the importance of particle size does not appear to be sufficiently realised and the farmers continue to use large quantities of lump quicklime, which as will be shown gives a very coarse product when slaked in the fields in the usual way.

Probably most of us when walking in the country have passed heaps of quicklime obviously intended for distribution over the soil when it has become slaked, and have wondered how a proper distribution of the caked and consolidated or sometimes more or less putty-like mass could possibly be achieved. A study of this method of liming, particularly in Cheshire, has shown that nothing approaching even distribution is achieved when quicklime slaked in the fields is used. Part of the slaked lime is not infrequently spread as caked masses several inches across; most of the remainder in small lumps; and a comparatively small amount as fine powder. This means that considerable areas, often about one-third of the total area, receive practically no lime at all. The hard cakes or sloppy masses are not broken up by weathering and not very much by harrowing. The final result is that part of the ground is overlimed (which may be deleterious in some cases) and part is not limed at all, for there is little or no sideways spread of lime in the soil.[4]

Consideration of the process of slaking lime in the open shows that caking with or without sludging of some of the lime is inevitable; neither dew nor atmospheric aqueous vapour will slake lime in a reasonable time; and before the rain can reach the centres of the heaps of quicklime the outer layers are bound to be overwetted. On drying the wet portions cake like mortar partly as a result of the semicolloidal nature of slaked lime and partly by the action of the carbon dioxide in the air.

In order to study the slaking of quicklime by outdoor atmospheric action a few brief experiments with lumps of quicklime were made under conditions intended to include the the effects of both wet and dry weather. Single lumps of quicklime were exposed out of doors for 1 to 3 weeks; some fully exposed and some protected from the rain but open to the weather round the sides. The products were tested by sieving. In only one case was any appreciable amount of really fine

powder produced—the sample which was protected from the rain—and then only 37 % of the product passed a 60 mesh sieve, 57 % being larger than a 10 mesh sieve, after 3 weeks outside. Samples taken from two heaps of lime belonging to local farmers gave similar results. The better of the two gave only 1·3 % through a 100 mesh sieve as compared with the 50—80 % less than a 100 mesh specified for ground limestone.

Alternatives to lump quicklime, apart from ground limestone.

These are:

(1) Ground quicklime. This is a fine powder which can be efficiently distributed with mechanical apparatus. It is, however, more expensive than lump lime, and in addition its use is very often quite impracticable, for if it is not spread within a week or two of delivery it is very likely to burst the bags owing to premature slaking by atmospheric moisture. It is also a very unpleasant substance to handle.

(2) Hydrated lime. This is too expensive for agricultural work and is very unpleasant to handle in large quantities. It cakes and carbonates when wetted and does not powder again on drying, as does ground limestone.

For practical farming purposes the choice is, therefore, generally speaking, between lump quicklime and ground limestone or ground chalk.

Two criticisms are frequently made of the carbonate of lime (ground limestone or chalk); firstly, because of transport charges it is said to be as a rule more expensive than quicklime, because its lower content of calcium oxide involves application of a larger quantity; and, secondly, it is less soluble in water, and is therefore assumed to be slower in its action than hydrated lime.

The following considerations indicate, it is contended, that both these criticisms are inapplicable in actual practice; in fact the reverse may often be nearer the truth when lime slaked out of doors before distribution is used.

Relative Costs of Quicklime and Ground Limestone or Ground Chalk.

(1) Quicklime after slaking in the fields has to be spread by hand shovel, hard and unpleasant work, which is more costly

and less efficient than the mechanical distribution of ground limestone.

(2) Distribution of slaked quicklime is admitted to be so inefficient that only when heavy dressings have to be given should lime slaked in the fields be used. It is stated in Ministry of Agriculture pamphlets[3] [4] that 2 tons per acre is the smallest amount of lime slaked by atmospheric action which can be spread efficiently. This is a very heavy dressing, and is about the same weight as is commonly recommended when ground limestone is used. F. P. Stowell[5] states that one ton per acre may be taken as a normal dressing of quicklime. Thus there seems to be little doubt that nearly as much quicklime as ground limestone is often used because of the difficulty of distributing the quicklime after it has been slaked in the fields. If 50 % more quicklime is used than is theoretically required, the cost including carriage will be the same as it would be if the theoretical weight of ground limestone had been used. Thus in actual practice ground limestone may cost no more, because none of it is wasted as is the case with quicklime. Lumps of caked lime are of little value in future years as is sometimes stated as they do not break up on weathering.

Relative Solubilities.

The statement so often made in the literature, e.g. Refs. 5 and 6, that ground limestone is slower in its action than slaked lime, is no doubt based on the solubility figures. According to these figures slaked lime is, as stated before, very much more soluble than the carbonate, but as it rapidly becomes converted to the carbonate by the carbonic acid in the air, we are in fact dealing with the same substance shortly after the material has been spread, whether we started with slaked lime or ground limestone. The rate of solution is the factor with which we are concerned in practice, and it is probably correct to state that rate of solution is substantially proportional to the surface area of the material, i.e. to its state of subdivision, and in this respect, as has been shown, ground limestone is greatly superior to quicklime slaked out of doors, the particles being estimated to be roughly one-tenth the size of those of the slaked lime (probably smaller). Ground limestone is usually sold as 50 % or 80 % passing a 100 mesh sieve.

Summing Up.

Carbonate of lime (ground limestone or ground chalk) apparently costs no more per unit of *available* calcium oxide equivalent than quicklime as commonly applied; a mechanical spreader can be used and it can be distributed evenly and efficiently; it is very much pleasanter to handle; it is harmless to plants (including seedlings) and to animals; it is in practice equal or superior as regards rate of dissolution; and it is efficient for the purpose in view, whereas lime as commonly used (lumps slaked in the fields) is considered to be very inefficient.

In view of the superiority of calcium carbonate it is difficult to understand why quicklime is still so largely used, and also why its use is encouraged by a subsidy as favourable as that for calcium carbonate.

Although the Ministry of Agriculture bulletin states that calcium carbonate may nearly always be relied on to give as quick and as good results as burnt lime, it adds that 1 ton of good burnt lime equals about $1\frac{3}{4}$ tons of limestone[7]; this makes limestone more expensive. Most of what has been said above in criticism of quicklime will be found in the bulletin, and the good qualities of the carbonate are brought out, but on the whole, in the writer's opinion, the impression is left that the carbonate is as a rule more expensive than quicklime, and that it is slower in its action on the soil.

A leaflet on carbonate of lime issued by the Ministry of Agriculture in 1943 states that the production of quicklime is restricted and that it should be reserved for arable crops such as wheat, barley, sugar beet and other roots; but that ample supplies of carbonate of lime are available which can be used safely on any crop. The impression is thus given, in the writer's opinion, that quicklime is superior and that the carbonate is just a substitute. Nowhere has the writer seen a recommendation that a general change-over from quicklime to the carbonate is now overdue.

In some cases where transport charges are heavy, ground quicklime may be more economical if it can be delivered to the site before it has burst the bags, and spread and harrowed in

before it has been wetted by rain or dew. But for lump quicklime which has to be slaked before use it is contended that no case can be made out unless the carbonate is unavailable.

, It suggested that the farmers should in their own interests be encouraged by more definite recommendations and suitable adjustments of the subsidies to discontinue the practice of using quicklime, now that the carbonate is available in suitable form. The change-over would in addition save the coal used for burning limestone.

References.

(1) W. Morley Davies, "Chemistry and Industry", 1944, p. 32—33.

(2) Min. of Agric. Bull. No. 35 (1943) "The use of lime in Agriculture", p. 18.

(3) Ibid, p. 9.

(4) "Growmore" Leaflet No. 41, "When land needs lime" (Min. of Agric.).

(5) F. P. Stowell, "Chemistry and Industry" (1943), p. 384.

(6) See 2, pp. 9 and 18.

(7) See 2, p. 17.

Birth Rates and Death Rates of Invention.

By W. A. SILVESTER.

In beginning to deal with this theme, no definition of "invention" will be given; but it will be said that for easily picked up and handled statistics of invention one must turn to the publications of the Patent Offices. In the patent offices of the larger industrial states the flow of business has no such short-term large ups and downs, except in war-time, that confusion will arise by taking, for present purposes, specimen figures. For the 10 years 1930—1939 inclusive 1936 was, near enough, an average year. In that year patenting activity, in offices dealing with more than 7,000 applications a year, which is over 20 a working day, was as follows (Ref. 1) :—

TABLE I.

Country.	*Applications.*	*Grants.*
U.S.A.	62,740	40,215
Germany	56,163	16,750
U.K.	35,867	17,819
Japan	18,511	4,836
France	17,698	16,700
Canada	11,928	7,895
Italy	9,089	11,870 (presumably arrears taken up)
Switzerland	7,879	6,822

Note.—The time-lag between application and grant differs from country to country: in some countries a time-limit is prescribed; in others not.

Other countries with substantial patent office business were Austria, Czechoslovakia, Belgium, Sweden, Australia, Holland, and Hungary.

Already in Table I the effect of differences in laws and office practices can be seen: the U.S.A., U.K. and Canada fall into one group accepting almost on novelty alone (as the phrase goes) about two-thirds of the applications made; France, Italy and Switzerland make no novelty search and grant patents, if all application fees are paid, almost for the asking regardless of whether the alleged invention is new or not; Germany and Japan attempt to size-up on novelty, *and* on demonstration of comparative utility, before grant.

Roughly speaking, all countries ask that a patent shall be for *one invention* only, and almost all countries limit inventions to new articles of utility or processes of *industry*. This is as near a definition of " invention " as can be given, and must suffice for present purposes. Not all patenting is done, per invention as so indicated, in more than one country. About half the French and Swiss patents were grants to foreigners (Ref. 2), and more than half the British patents were to " outlanders " From the statistics available (Ref. 3) the following table of " home-made " inventions may be compiled —

TABLE II.

DOMESTIC PRODUCTION OF INVENTIONS CIRCA 1936 (ROUND FIGURES)

Country	*Population in Millions*	*Patent Applns*	*Grants.*	*"Birth rate" per million population per annum* A	G
U.K	46	23,000	8,700	500	187
U S.A	129	53,000	35,000	410	270
Germany	71	47,000	13,600	660	191
France .	42		11,000		260
Switzerland .	4		3,200		800

Let there also be added (Ref 4) ·

U.S.S R	166	2,271	14

As already said, neither in France nor in Switzerland is there a Patent Office novelty search. But, furthermore, in Switzerland, oddly, (i) no patent for chemical products may relate to more than one substance (which makes for more apparent inventions in Switzerland than elsewhere); and (ii) there may be no patenting of chemical treatment of textiles (which makes for less apparent inventions in Switzerland than elsewhere). Allowing—which is no more than a guess (and perhaps not a very good guess)—that these factors balance one another, and also disregarding for these two countries

applications not pursued to grant, then one may say that the order of fecundity in industrial ideas (notions per mill. populations per annum) for the prolific countries is shown as follows :

TABLE III.

Switzerland	800
Germany	660
Holland	580
U.K.	500
U.S.A.	410
France	260

Note 1.—Here a figure also for Holland is given.

Note 2.—If one disregards that part of the population of the U.S.A. which is not white (c. 14 mill.) then the figure for the U.S.A. rises to 460.

This is the order when the measure is that of notions in the minds of people who think they have thought up or found out something new and useful ; wish to monopolise by patenting ; and are prepared to spend money on the initial steps. One comment can be made ; in U.S.A. patent agents advertise their skill, with much show of the advantages of employing them, even in school-boys' magazines ; in U.K. they do not, but Britain has been at comparable times more prolific of notions even than "white" U.S.A.

Although there is much bureaucratic subdivision of notions in U.S.A. patent office handling, yet, allowing also for opposition possibilities in U.K., the killing of notions at the patent office stage (i.e. the finding that the notions have already been described in print) proceeds at about the same rate in the two countries. In some other countries the mortality rate at this stage is much higher, for reasons already sketchily indicated. Only for two can, *perhaps*, a direct comparison be made, viz. :

Novelty-and-comparative-utility-demonstrated inventions, number per million population per annum circa 1936.

Germany	191
U.S.S.R.	14

Although political circumstances are in various ways different and a strict comparison can hardly be made, that the U.S.S.R. has not been fertile in expectedly saleable patent-claim-defined inventions can be judged also from the grants of British patents to Russians, which averaged 8 a year between 1930 and 1937; in 1937 the *British patents granted* included 3,752 to German nationals, 3,204 to U.S. nationals, 11 to Russians, and 2 each to Chinese and Greeks.

In China there is not, visibly, any amount of inventing; in that country there has never been a patent law worth mentioning, and the absence of a patent law offers some evidence that no inventing is done. Of some of the ancient breeding grounds of mankind: China, the Ganges Valley, the Nile Valley, Mexico, only British India has a developed patent law, but native Indian inventing remains negligible in volume, when the magnitude of the population also is taken into account.

The fermentation of knowledges, skills, and urges, hitherto limited for industry based on "science" (although not limited for art) almost wholly to N.W. and Middle Europe and the U.S.A. may not persist there, perhaps not anywhere. The "birth rate" of inventions was, seemingly everywhere, on the decline already before the outbreak of World War II in 1939. Comparisons are difficult as changes are made from time to time in patent laws. But not only were there indications of an absolute decline in all major industrial countries but almost certainly the numbers of patent applications were not rising anywhere in proportion as population increased (Ref. 5 and cf. Ref. 3). Between 1922 and 1938 the peak year in Germany was 1930 with 78,400 applications (62,651 "domestic"); after a drop to 52,856 (43,114 "domestic") in 1934 even "Forschung tut not" did not bring the number up beyond 57,139 (48,510 "domestic") in 1937 to fall again in 1938. In U.S.A. the figures fell, irregularly, from 88,000 odd in 1921 to 65,000 in 1937.

So also in Britain, for domestic inventions, there is a fall. For granted patents on domestic inventions the rate of issue also falls off gradually from 1928. These trends are shown in Table IV.

TABLE IV.

PATENT APPLICATIONS AND PATENTS IN U.K.

Year.	*Total.*	*Domestic.*	*Grants of patents on "domestic" applications.*	*Population in millions.*
1920	36,672	24,337	9,186	
1921	35,132	26,052	9,084	c. 44.0
1922	35,494	27,434	9,412	
1923	32,621	24,454	8,656	
1924	31,370	21,894	+	44·9
1925	33,003	22,479	+	
1926	33,080	+	+	
1927	35,469	23,390	9,109	
1928	38,556	24,926	9,819	
1929	39,898	24,170	9,775	
1930	39,359	25,014	9,678	
1931	36,117	22,993	9,008	46·07
1932	37,052	25,128	8,900	
1933	36,734	24,330	8,668	
1934	37,409	24,424	8,797	
1935	36,116	22,786	8,674	
1936	35,867	22,345	8,549	47.08
1937	36,266	21,940	8,629	47.29
1938	37,973	23,578	—	47.48
1939	33,109	21,329	—	—

+ — Gap in present writer's notes.

The Population figures except for 1921 are taken from Statistical Abstract for the United Kingdom, 82nd number (Cmd. 5903), H.M.S.O. 1939, Table V.

In totting up the "domestic" applications the effect of the separation of Eire has been disregarded (only the hundreds figures are affected).

Translating some ingredients of Table IV into figures to correspond with those of Table II, it can be said that the "birth rate" of domestic inventions per million population in England and Wales was almost exactly 600 in 1921–25 inclusive, but had fallen to 562 for 1931–35 inclusive and continued to fall up to the outbreak of war.

In passing it may be remarked that the highest recorded figure for patent applications from Scotland was in 1922 with 1,376 applications, and the lowest in 1939 with 689 applications.

Even in the U.S.S.R., despite state provision of incentive and the existence of an All-Union Society of Inventors with 800,000 members (membership is not limited to accredited inventors), the authorship certificate grants fell off earlier and did not rise between 1936 and 1940 (Ref. 4).

In some of the British Dominions the greater part of the patenting is done by "outlanders". In the between-wars period the volume of total business tended to increase, the pace being set, seemingly, by the activity of U.S.A. firms. The trends are particularly noticeable in the statistics for Canada, where in 1937 64 % of the total patenting was done by denizens of, i.e. nationals of or residents in, the U.S.A. Canadian patenting by Canadian inventors was not rising in volume in the between-wars period.

Most patents, at time of grant, at least in Britain, represent inventions still in a stage of "gestation". This is true at least for chemical inventions (Ref. 6). In all countries where Government demands renewal fees for keeping patents in force the mortality rate of patents is high. The U.S.A. has no such renewal fee provision; all patents stay in force for their full term unless litigated, and hence some of the internal troubles over monopolies in the U.S.A. The obligation to consider renewal fees had almost the same effect in Germany as in the U.K. In both countries mortality of patents was high up to about the sixth year of life. At 14 years of age (which was the original British full term of the Statute of Monopolies) only about 10 % remain alive, both in Britain and Germany. Thus one can say, roughly, that of the conceptions thrown up and crystallised into patent applications, in Germany only about 3 % become at any time substantial market actualities, and in Britain perhaps up to 5 % on the same kind of reckoning.

Table V gives some illustrative figures (from first two items under Ref. 3).

TABLE V.

Total Numbers and Percentages of Granted British Patents of year 1924 and of Granted German Patents of year 1924 alive from the fifth year of life onwards.

Year of	*British.*		*German.*	
Life.	*Total.*	%	*Total.*	%
5	9,005	57.6	11,585	64.7
6	7,313	46.7	9,687	54.0
7	5,979	38.2	7,871	44.0
8	4,662	29.8	6,262	34.9
9	3,665	23.4	4,511	25.1
10	2,971	19.0	3,466	19.3
11	2,506	16.0	2,696	15.0
12	2,145	13.7	2,303	12.8
13	1,857	11.9	2,025	11.3
14	1,631	10.4	1,983	11.0
15	1,371	8.8	1,836	10.3
16	936	6.0	—	—
17				
18				

The renewal fees in Germany for the later years of patent life are higher than in Britain, consequently it can almost be said that for those patents kept in force for more than about a dozen years the expense of renewal fees has become negligible, and only the technical outlook governs the fate of the surviving 10—11 %, fourteen years old. The agreement between the percentages in the two countries is, nevertheless, remarkable.

So much for death rates of invention as represented by figures from which expectations of life of supposedly new industrial *notions* could be calculated. What now is the death rate of "established", i.e. marketed inventions? It seems to be a common supposition that few die, but the contrary is suggested by even a cursory glance at the history even of warfare. However, specimens for illustration can readily be drawn from other fields of human activity than that of warfare. Thus: sedan chairs had but a short life, in England about 100 years from 1649; whalebone was first used in corsets in

1617 (Ref. 7) and was still so used within the last forty years, so this invention had a life of about 300 years. The prehistoric sickle and the itself ancient scythe were displaced in the harvest field by reaping machines about 80 years ago, but some reaping machines have not survived (cf. Ref. 11). Devices for time and other measurements, etc., provide many more instances of extinction of both major development and minor improvements; who, nowadays, has heard of Suxpeach's "catholic organon" or universal sliding foot rule? Within the last 150 years there have been many spates of marketed invention followed rapidly by elimination of competitive weaklings of which perhaps electric telegraph devices from about 100 years ago and azo dyestuffs from about 50 years ago deserve mention as providing further typical specimens. With so varied spans of life and often no clear distinction between death and betterment no death rates can be worked out. All that can be said is that some inventions have had long market lives; some short.

But nowadays, one is told, the lives of inventions are to be expected to be short. No war, panic, bank-failure, strike, or fire can destroy a business as can a new and better product in the hands of a competitor. This is one picture given by an American writer, Bichowsky, who also said (Ref. 8) that by 1870 the canal was most certainly dead (The Netherlands, and the Old World generally, overlooked?). Bichowsky, remarking that nobody likes a change, nevertheless proceeded to give another picture. He spoke of the need for a constant research for novel and smart-looking new gadgets to supply a style-conscious market. This, however, it seems, may lead not to something better but only to something different, "as, for example, molding plastics have largely displaced hard rubber even in fields where hard rubber is more suitable and cheaper". About 6½ generations ago, Dryden in the *Annus Mirabilis* contemplated the Royal Society's drawing rich ideas "to fit the levell'd use of human kind"; some, at least, of the crop of ideas spoken of by Mr. Bichowsky may fit such levelled use in space or some part thereof, but not in time. But, perhaps,

shopping mankind may not continue to be so style-conscious: even in mass psychology le Chatelier's rule may apply.

To expand the field of conjecture, the data given herein may suggest that, even in this branch of human activity, there are limits to possibilities as affairs become more complex, or, as also the statistics may suggest, the present noble, or at least technologically inventive, races of mankind may be tending to become extinct (Ref. 9).

Perhaps "western" mankind, or at least mankind in the United Kingdom, is merely approaching the beginning of a generation of thrift in a three-generation cycle of thrift, stability, and waste, as was suggested by Flinders Petrie in 1938 (Ref. 10). Or perhaps, indeed, the peoples of the West are glimpsing the end of their "scientific" age, as also was suggested by Flinders Petrie, over thirty years ago, as a possible deduction from history.

Postscript.

That which appears above is substantially as read at the meeting of the Society on November 20th, 1945, the matter having been collected as gleanings made in other studies. In looking for further literature on such themes the writer encountered the book by Gilfillan (Ref. 12). This book contains a voluminous bibliography. Mr. Gilfillan had found that inventive activity measured by U.S.A. patent office units had risen almost exactly in proportion to population in U.S.A. up to the 1920's, but was showing a tendency to fall off, which was contrary to some of his "principles", i.e. his generalisations, as chiefly deduced from the history of ships. Mr. Gilfillan discusses, as explanations (A) postulating a decline in inventiveness in U.S.A., (i) the effect of standardisation, (ii) the effect of the use of enduring materials, (iii) the effect of a decline in "native ability" in U.S.A., (iv) the effect of some kinds of technical training in giving rise to conservative professionalism (generation of a cult; some evidence of such among engineers alleged); and as explanations (B) postulating no decline in inventiveness but only a decline in patenting activity, (i) the

effect of accumulation of prior art, (ii) the effect of increase in size of firms, (iii) the effect of changes in business behaviour—trend towards more urbane co-operation, (iv) the effect of having persons employed to invent, (v) the effect of improvements in professional standards for patent attorneys (there is a quaintly American note struck here), and sundry other less clearly defined conjectures Earlier in his book he considers the possible effects of a diminished rate of increase of American population As to this and with some reference to abilities, an American patent attorney (Ref 13) observed already in 1921 that "immigration will probably never again supply us so generously with *laborers* as in the past" (present writer's italics).

In his discussion Mr Gilfillan appears to the present writer not always to keep in mind that all inventions, even supposed inventions, have uniqueness of circumstance Applications in patent offices are made mostly by or for one person as inventor, fairly often for two as joint inventors, seldom three, and still more seldom four or more One must then always distinguish between (1) the state of mind of the average inventor (or joint inventors)—especially in Great Britain, with provision under British law for application at low fee, with provisional specification—including his own concept of his invention at that time, (2) the measure of an invention for patent law purposes, and (3) the measure of an invention as more popularly understood, i e as a marketed article or substance, etc As indicated above American patent law is such that U S law and U S Patent Office statistics (including those of patent *applications*) do not suit present purposes quite so well as British law and British Patent Office statistics The period of time between British application date and end of fourth year of patent life when the first renewal fee is due, is also, roughly, the period of scientific gestation (cf Ref 14, and Ref 6, page 12), whilst the market-acceptable survivors of the period of industrial gestation (to use again the late Lord Stamp's expression) are represented, roughly, because for instance of bunching of units of invention by law in one commodity, by the British patents which are still in force in their sixteenth and normally last year of life These measures are lacking in U S Patent Office statistics

The numbers of British patents in force for the 16th year of life (N.B.—The term was extended from 14 years to 16 years by the 1919 Act so that the percentage figures are not strictly comparable) were as follows :—

Year of Application.	*Number.*	*% of those Granted.*
1906	597	3.6
1907	677	4.2
1908	650	4.1
1909	752	4.6
1910	737	4.6
1914	758	6.3
1915	576	6.3
1916	519	5.5
1917	462	4.5
1918	479	4.1
1919	620	3.7
1920	630	3.5
1921	735	4 6
1922	901	5.8
1923	984	6.6
1924	936	6 0

These figures, themselves perhaps just about large enough to be significant for statistical purposes, need, however, a further breakdown to show, at least :

(*a*) patents on inventions made in the U.K. ;

(*b*) patents on inventions made abroad (and at least in which larger industrial countries) and perhaps also by fields of industry. All of this would need examination of the records of each case for a representative sample of cases before deductions as to rise or fall in materially fruitful inventive fecundity in the U.K. itself could be made, and even then the necessary allowance for the effects of war might leave conclusions vague. Moreover, to compare in this way among themselves, year by year, the patents of the applications made in the between-wars years one must wait until 1954.

Note.—Few inventions are "great" by popular measure, if measure it can be called (Ref. 18). And few inventors, even in likely fields, are inventors of more than one marketed invention (cf. Ref. 19). A convenient list of a variety of

inventions which long since passed the stages of scientific and industrial gestation has already been mentioned (Ref. 7, second item). As extreme specimens of marketed invention in two fields of industry there are that of Hilger's patent which was extended for 10 years (Reports of Patent, etc., Cases, XLIX, 245), and an electric hair-comb device the subject of an invalid patent (*ibid*, XLVIII, 405).

To return to the decline in patenting: against Gilfillan's "explanations" B (ii), (iii) and (iv), it can be said that even in U.S.A. the greater part of the patenting which is done is not done by large firms; in 1938 77 % was done by individual persons or small firms (Ref. 15). Of "explanation" B (i), which needs analysis, it can at least be said that it does not allow for the infinite possibilities of logical differentiation in the writing of claims, whether or no attempts to apply "flash of genius" measures are made. Hence a European can perhaps disregard entirely the given "explanations" which postulate no decline in inventiveness. As to the other explanations the present writer himself "postulated", before reading Gilfillan, as a hypothesis with support from history, that there could be and seemingly was a decline in "native ability". It must suffice here to suggest further that in attempts to discover causes of the phenomena seemingly credibly displayed in the Patent Office statistics, some consideration be given to: (i) the effect of the fall in the birth-rate in U.K., which began before 1880, but which did not proceed uniformly, the rate of fall being different, in the period of time to be considered, in the different social classes (cf. Ref. 16); (ii) the effects of "Englands Kampf um den naturwissenschaftlichen Unterricht" (Ref. 17) *and* of the continued increase, through academic research, of the subject-matter of science, so that there is, *perhaps*, a trend towards making particular sciences into progressively, linguistically elaborate book-learning cults of particular groups of growers-up sitting for H.S.C., etc., with, again conjecturally, fall in output of experimentally-minded budding savants to be employed in some of the staple industries. Also as to trends in the universities and colleges, it is now 20 years—so more than half a generation—since Professor W. P. Wynne made a survey in his Presidential Address to the Chemical Society of 1925.

To bring this postscript to an end it may perhaps be said that the United Kingdom with its 47 million inhabitants has at the present time 400 or so sturdily upgrowing offspring of industrial technique innovations a year. But, situated as it is, it can hardly take risks. On hindsight of sixteen years or so one can say that flashes of genius which lead to such offspring come, each year, to one individual in about a hundred thousand. But if circumstances become such that a nearly regular appearance of flashes of genius declines to a scatter of odd sparks, then these may do no more than cast a feeble glimmer over a heap of embers.

But others have written on such aspects of the theme at length (Ref. 20).

Samuel Butler, some 250 years ago, said :

> " All the inventions that the world contains,
> Were not by reason first found out, nor brains ;
> But pass for theirs who had the luck to light
> Upon them by mistake or oversight."

But who, occupied in industry, will agree ?

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17 Conferences in London in May, 1916, reported in detail in German in Ahrens' *Sammlung Chemischer und Chemischtechnischer Vortrage, XXIII*, Heft 11—12, Stuttgart 1917 cf *Natural Science in Education*, London, H M S O, 1918

18 *World Almanack and Book of Facts*, 61st Year, New York, 1946, pages 248—249 141 "Great" inventions made in U S A since 1752 (Franklin—lightning rod), 106 "Great" inventions made in the rest of the world since 1581 (Galileo—pendulum)

19 *What Industry owes to Chemical Science*, 3rd edn (Pilcher and Butler-Jones and others), Cambridge, 1945, page 125

20 Of the copious literature in various languages—much referred to by Gilfillan—it will suffice here, because of the importance in industrial civilization of the chemical industry, to mention (i) Bloch, M (Professor, Leningrad) "*Uber einige Gesetzmassigkeiten im Schaffen hervorragender Chemiker*", Berlin, 1931, and (ii) Schmidt, A, *Die industrielle Chemie in ihrer Bedeutung im Weltbild*, Berlin and Leipzig, 1934, Chapter VI . die Frage, wie weit kann das technische Erfinden eine erlernbare Kunst sein ?

Notes on the Gaskell Collection in the Central Library.

By Marian V Malcolm-Hayes

The Gaskell Collection, which illustrates the life and work of the Rev William Gaskell and Mrs E C. Gaskell, was originated by Mr. W. E Axon, Chairman of the Moss Side Public Library Committee, and built up by Mr J A Green, the Librarian. Since the incorporation of Moss Side with Manchester it has been cherished as one of the Special Collections in the Central Library Most Gaskell biographers have used it, and students of Gaskell literature owe much to the thought and care with which it has been brought together

The Collection is housed in two tall cases on the second floor It consists not only of the various editions of Mrs Gaskell's works, and of Mr Gaskell's sermons, lectures, hymns and poems, but also of books and pamphlets from Mrs Gaskell's own library which illustrate her way of life, her main interests and literary contacts, her intimate friendships and family affairs We can see here early numbers of the periodicals in which so many of her novels and short stories appeared, and there are albums of cuttings and boxes of photographs which provide fascinating material for biographical research. Besides all these the Collection contains certain treasures, autograph letters, MSS and music transcribed by Mrs Gaskell and her friends, which are, of course, kept in the strong room, but which are available for inspection on the premises with the permission of the Librarian

In 1895 Messrs Wm and Ernest Axon together presented a bibliography of Gaskell writings to the Manchester Literary Club, and copies of this pamphlet can be seen in the Collection. In 1903 Mr. J. A. Green compiled a hand-list of the Collection as it then existed, and in 1910, the year of Mrs. Gaskell's Centenary, he published a full Bibliographical Guide. This is arranged in nine sections, the second, Biography and Criticism, being sub-divided three times. In the short time at my disposal I cannot do more than glance at some of these, touch lightly on others, and comment briefly on one or two. I have chosen Sections 2 (Biography and Criticism), 6 (Periodicals), and 8 (Works by the Rev. William Gaskell) for special mention, and hope to say something of No. 3 (Autographs and MSS.) before I close.

Mr. Green's first heading is Bibliography, his fifth Collected Works, his seventh Chronological List. Only a trained Librarian could do justice to these; I will merely mention more recent additions and indicate some items of special interest. Additions, including volumes from Mrs. Gaskell's own library, were made to the Collection at the time of Miss Gaskell's death in 1914, and in 1911, 1915, and 1922 Mr. David Hutcheson, of Newport and Washington, made gifts of American editions. No very recent catalogue is available, and no comprehensive list could be made under the difficult circumstances of recent years. It is hoped therefore that the few notes and comments which follow may be of interest to Manchester people.

Editions.

Forty editions of "Cranford" are listed, and one shelf is filled with its translations, adaptations, and dramatizations. Here it is in de-luxe editions, in pocket editions, as a gift book, and a bedside book, in school editions, in cheap and nasty editions, and in beautiful and sedate volumes for the glass case rather than the hand. And yet it made no great stir when it first appeared in "Household Words", though Charles Norton said that in five years' time it was beloved from Maine to California.

Five novels and the Brontë biography were published in Tauchnitz; most of these and some foreign editions were presented by Mr. W. E. Axon. The translations are interesting; it seems that Germany chose the grimmer and more sensational tales, "Die That einer Nacht" and "Sylvia's Freier", while France preferred the domestic novel and the romantic love story, "Cranford", "Marie Barton", "Nos Femmes et Nos Filles", and the hustling Americans took the short stories. Mr. Hutcheson's bequests include several early publications which present Mrs. Gaskell's "Lizzie Leigh" as the work of Charles Dickens. These are "Pearl Fishing" (1854), Harper's "New Monthly Magazine" (1850) and "Dickens' New Stories" (Peterson—Philadelphia). Most of the American editions were issued on inferior paper and in poor type with sketchily reproduced illustrations, and are almost certainly piracies.

The English 1860 edition of "Right at Last" carries a humble preface by Mrs. Gaskell, in which she implies that only

her publishers' importunity has caused her to allow them to issue this volume of collected tales, and she supposes they must know best.... A first edition of "North and South" has a rather indignant preface excusing her "hurrying on events with an improbable rapidity" which she protests was forced on her by the exigencies of weekly publication (in "Household Words"). Dickens, we now know, liked to include an episode every ten pages in a weekly number.

There are many cheap editions of "Mary Barton", crumpled and thumbed; three of them at 1d., one in "Popular Novels", one in "Famous Books", and one (abridged) in the Masterpiece Library. A copy of the rare fifth edition, which includes Mr. Gaskell's two lectures on the Lancashire dialect, is inscribed to Ann Swift, who was a Sunday School pupil, from "her sincere friend E. C. Gaskell, April 20th, 1854". Dion Boucicault's dramatized version, "The Long Strike", in four acts and with 25 characters, is here, too. It was performed at the Lyceum, and the curtain was brought down to a triumphant cry of "Not Guilty!" with great applause.

The first and second editions of the Brontë Life are here, with the wrathful and indiscreet passages on Branwell's love and despair still included. And a dull American novel, "Mabel Vaughan", by Miss Cummins, has a preface by Mrs. Gaskell, in which she stresses the need for Anglo-American friendship and understanding, and notices the advantages of the American institution of the At-Home Day, borrowed from France.

The first American edition of "Wives and Daughters", paper-backed and double columned, with du Maurier illustrations, has a marginal comment in pencil, "What would Mrs. Gibson say to the manner in which Mollie Gibson's hair is dressed?"; it is certainly an anachronism, for the long locks stream down her back in a very easy manner. Mrs. Gaskell was not always happy in her illustrators. The early work of du Maurier and Birkett Foster does less than justice to author and artist. With the exception of an exquisitely engraved frontispiece by Guilbert to "My Lady Ludlow", most of them tend to be prettyish and nondescript, reflecting the male artist's impression of the authoress's sentimental vein; only H. M. Brock has caught the humorous aspect of her work.

Portraits and Views: Topographical and Miscellaneous.

Sections 4 and 9 announce their own contents. They consist of carefully selected cuttings picturing Mrs. Gaskell, her husband, her family, her several homes and holiday haunts and the many places traditionally associated with her life and work. There is a delicate pencil drawing of Pepperhill Farm by Tavaré, there are the Rev. Mr. Sargisson's 37 photographs of Knutsford, etc., some large press studies of the drawing and dining rooms at Plymouth Grove, reproductions of the Dunbar bust and the Richmond portrait, of the house in Chelsea where she was born, the church in Knutsford where she was married, and the chapel acre where she was laid to rest. All these formed part of an Exhibition which was held in the Central Library in 1914, and with them were shown some of the autograph letters already mentioned. The Catalogue which Mr. Green prepared for the Exhibition gives the text of these letters, and a copy of it can, of course, be seen in the Collection.

Biography and Criticism.

Under this heading Mr. Green's sub-divisions are (i) Biographies, (ii) Biographical, critical, and anecdotal, (iii) Periodical Articles. There is one omission, Mrs. Gaskell is not represented here by any collection of her own letters. A most important item is undoubtedly the complete set of the late Sir Adolphus Ward's prefaces to the Knutsford Edition of the Collected Works, which have been bound in one volume and presented by the publishers. Besides these, Mr. Ross D. Waller's fascinating selection of letters from Mrs. Gaskell's contemporaries, published for the John Rylands Library, can, of course, be consulted in the Reference Section, with other standard biographical and critical works.

In a letter to Miss "Tottie" Fox, written about 1850, Mrs. Gaskell speaks of herself as possessing "a great number of 'Me's'". "One", she says, "is I believe a true Christian, only people call her a Socialist or Communist, one is wife and mother, one has a full taste for beauty and convenience". In the context she is excusing herself for expenditure on a greenhouse at Plymouth Grove, but surely these are three of the many threads which run through her life as Social Worker, Housewife,

and Artist ; they indicate conveniently, too, the three phases of her literary progress, and are amply illustrated by the contents of this section of the Collection.

A portrait of Aunt Lumb in a beautiful mutch reminds us of Elizabeth Stevenson's happy childhood at Knutsford. Her schooldays at Stratford are suggested by a rare pamphlet by her father, William Stevenson, on the " Inferior Utility of Classical Learning ". He maintains that the study of Classical Literature is " not the most effective means to the most important end of education, which is a knowledge of facts and the deduction of simple and useful truths". " If Herodotus", he says, " believed all he wrote, we must condemn him for his credulity, if he did not, we discover a want of judgment ". He denounces as " improper and even criminal " the practice that devotes several years to " a study whence the mind receives no knowledge, and the imagination but little pleasure, which cannot improve, because it does not exercise the judgment ". From him his pretty daughter would seem to have inherited her independence of mind, and his influence probably helped to procure for her a far more liberal education than most of her contemporaries received even in enlightened Unitarian circles. At the Misses Byerley's school at Stratford she acquired a good working knowledge of French and Italian, and the small MSS. book into which she copied songs and hymns in three languages is one of the treasures of the Collection. It is beautifully written, and is inscribed " E. S Stevenson, Avonbank. Jan. 15th, 1825 ", and, a pleasantly authentic touch, " Thursday ".

There is evidence, too, of a life of cultivated leisure in Edinburgh, and at Newcastle, where she attended meetings of the Literary and Philosophical Society, and as a young wife married to the Junior Minister of Cross Street Chapel, Manchester, she brought refined tastes into an ugly city. In one of the articles filed by the indefatigable Mr. Green she is described as very simply dressed, her beautiful arms bare of bracelets, and her hands always clean. Her house, we are told, was simply furnished and harmoniously decorated with old china and fresh flowers. From these surroundings, and with these tastes and aptitudes, she came into Manchester to teach at the Sunday School and Ragged School. Mr. Cobden Smith's Centenary address, " Mrs. Gaskell at Lower Mosley Street ", describes how

she did it. We cannot be surprised to learn that her Sunday scholars played instructive but amusing games, and that she mended their pens, cleaned their slates, and told them thrilling stories.

Mr. and Mrs. Gaskell are both mentioned in Evans' "Unitarian Worthies", which informs us that Mr. Gaskell preached in a silk gown to a "rather" aristocratic congregation, and that his chapel was currently called the "carriage-way to heaven"; but in the streets and alleys half-a-mile away there were pestilential cellar dwellings where cholera and typhus were expected as a matter of course. Here Mrs. Gaskell visited, and saw, with indignation, ailing women and neglected children. A lecture by J. A. Nicholls for the Manchester and Salford Sanitary Association on "Public Health considered in reference to the Physical and Moral Condition of the People", is shocking reading today. The Ladies' Health Society, which did not commence its benevolent activities until 1870, would have had Mrs. Gaskell's support. One of her earliest stories, after publication in "Howitt's Journal", was reprinted in aid of the Macclesfield Baths and Washhouses.

The Sanitary Association, in which Mr. Gaskell was interested, tried by the use of tracts and public lectures to educate the slum dwellers and interest public opinion in the rudiments of hygiene and the elementary rules of self-preservation. Mr. Nicholls says that "the absolute and extravagant waste of life is most fearful", speaks of a "dark, heaving inexpressible chaos" and "serried bands of almost hopeless ignorance and indifference" and proposes to "cleave their closed ranks with the sword of knowledge and truth". In an article in the Manchester Quarterly of 1932, which marks the centenary of Mrs. Gaskell's coming to Manchester, W. Henry Brown gives facts and figures for housing accommodation and street cleaning in 1842; the main streets cleaned once a week, secondary streets once a fortnight, the courts and alleys not at all, and it cost £5,000 a year to do it! 27,281 people lived in comfortable dwellings, 10,443 in uncomfortable dwellings, 18,000 in cellars! Mr. Gaskell was a member of the committee for the better regulation of Public Houses, yet he would probably have echoed Dickens on the true origins and causes of drunkenness in his native city as being "foul smells, disgusting

habitations, bad workshops and workshop customs, scarcity of light, air, and water, in short the absence of all easy means to decency and health ". But in justice to Manchester even Mr. Nicholls had to admit that the Civic authorities gave efficient sewerage " excelling any other district in the kingdom ", and the "Edinburgh Review", when it attacked "Mary Barton" five years later, said that " it was notorious that in no town were there better organized or more efficient charities than in Manchester ".

Taken with the privation and misery caused by bad trade, all this impressed Mrs. Gaskell deeply. She pondered on " what really does good among the poor ", and she took the advice of her own Nicholas Higgins, who appeared later in " North and South ", " Set to work ", he said, " on what ye see and know ", and so she did, and produced " Mary Barton ".

Landor wrote a bad poem in honour of her achievement, and among the reviews in the Collection is one by C.H.H., of the " Manchester Guardian ", in which it is said that " in painting industrial grime and squalor the quietness and precision of her realism is more searching and penetrating in its effect upon the sympathies than the more brilliant and highly charged slum pictures of Dickens ".

Included in the Topographical Section of the Collection are works by G. E. Payne on Knutsford, by H. T. Crofton on Old Moss Side, and by John Mortimer on Mary Barton Fields; these all help to set the scene. Moss Lane it seems was truly rural in those days; there were farmhouses there and a row of ash trees, and a duck pond and a stile at Pepperhill Farm. Primroses and violets grew under hawthorn hedges, and fallow deer roamed in a garden at Greenheys. Most impressive is a photograph of Plymouth Grove, which shows it in 1870, five years after Mrs. Gaskell's death, with grass verges set with flowering chestnuts, and elegant white posts and chains. Here she lived the life of the second " Me ", the Victorian mother, housewife and hostess, and much detailed evidence goes to show how expert she was in that métier.

Although there is no volume of her own letters in the Collection there is a shelf full of Reminiscences compiled by and about her friends and acquaintances, and from these we

can build up the background of her social life, and catch revealing glimpses of her character and personality. Here are the history of her friendship with the brilliant Madame Mohl, who arranged for the translation of several of her books into French, and the Memoirs of the clever Winkworth Sisters, some of Mr. Gaskell's favourite pupils, with one of whom she went " slumming ". Here also are the affectionate or sentimental recollections of Lady Ritchie, Thackeray's daughter, of Hannah Pipe, the advanced schoolmistress of Laleham, and of Mrs. Beecher Stowe, of " Uncle Tom " fame, who writes in her rather dreary " Sunny Memories " of the " sweet pathos of Mrs. Gaskell's expression ", but who seems to have missed the sparkle in her eye.

I should like here to include a note on the books from her personal and family library which have found their way into the Collection. It is probably not a truly representative selection, but contains much that is significant of her environment and family circumstances. It contains, too, a hint as to the direction in which her own literary efforts were likely to develop There is a fair amount of third-rate verse presented by her affectionate friends the authors, and several collections of hymns which include some sincere and shapely specimens of her husband's lyric gift. Among the travel books are a "New Guide to Warwick and Leamington ", which had belonged to Holbrook Gaskell in 1816, the " Railway Traveller's Walk Through Cambridge", with 75 excellent illustrations, a "Guide to Versailles", a "Guide to the Central Alps " (1864), and " Ninety Days' Worth of Europe ", this last the effusion of a globe-trotting young American, and just the sort of thing that Frank Churchill might have exposed himself by producing if he had made a tour in " Swisserland " instead of marrying Jane Fairfax.

There are also several children's books, " Little Fadette ", a domestic story by George Sand, is inscribed to " dear Mama from M.E.G.". A rather dreadful little tale, " Lucy's Half Crown. How She Earned It and How She Spent It, with some Hints on the Art of Making People Happy without Money ", was presented to the Miss Gaskell's Juvenile Library " in memory of some happy days ". The publisher's list on the end papers of this classic affords a glimpse of the juvenile

reading world of the time, it advertises "Six Short Addresses to Young Persons, on the scriptural origins of the Collects in the Common Prayer Book of the Church of England", and, we may rejoice to note, "Andersen's Tales from Denmark, The Nightingale, etc" With these is an aristocrat of the species, Mme Louise Swanton Belloc's "Pierre et Pierrette" (1849), presented with "humble hommage à Mme Gaskell ou plutôt à ses enfants" by the author This little work is described in the introduction as "ouvrage auquel l'Académie a décerne un prix Montyon, une medaille de 2 mille francs' and the introducer goes on to pay a tribute to Mme Belloc, which indicates what she had in common with the English authoress, and probably why she was selected by Mme Mohl to translate 'Cranford" 'L imagination", he says "est nécessaire pour gagner les âmes simples', and goes on to note that the little tale is 'conté avec un natural exquis, which he considers surpasses English work in the same field

When Mrs Gaskell wrote for children she did so in Travers Madge's Sunday School Penny Magazine, which he had founded in order that "young hearts reading these pages may be kept pure from childhood, and early consecrated to the service of God" The small brown volumes are included in the Collection and in "Hand and Heart' (July, 1849), Mrs Gaskell not only read the young people a little sermon but made them laugh and slipped in some hints on open windows and clean shirts We are glad to find, incidentally, that Mr Gaskell did not believe in the doctrine of original sin in little children, in one of his sermons he said so, but exhorted them to affection, faith docility, truthfulness, and readiness to forgive So he and Mrs. Gaskell were of one mind there as in so many things But he did not approve of prizes in Sunday School, and here I cannot believe that she followed him.

She was beginning to find her most congenial field in the woman's province, the practical warmed by sentiment, but as yet she hardly recognized this Her publisher did so for her In the Collection is preserved a cheap edition of "Mary Barton' (1856), on the flyleaf of which the author has written, "This story was first entitled 'John Barton' but at the publisher's request the name was changed to that which it at present bears, E C. Gaskell May 3rd, 1861" Thus the publisher would

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seem to have realized that she was *par excellence* a woman's novelist; and although much skill and care had gone into the portrayal of John Barton, and his were the problems and the ultimate tragedy, the shrewd man recognized that it was Mary Barton who would catch the public imagination.

Periodicals.

Mrs. Gaskell told Charles Norton, her American correspondent, that she could not write with an audience in mind; but a study of the periodicals to which she contributed gives us some idea of her audience, its members' tastes and fancies, modes and humours, tone and attitudes. In the "Ladies' Companion" of 1850 the Dear Reader of her own sex can be perceived, and we know for whom, perhaps unconsciously, she often wrote. Her own "Moorland Cottage" is reviewed here and judged to be "a healthy, powerful, and pathetic story in which fancy and feeling graciously consort with and are harmonized by virtue and reason". She was indeed fortunate! In a later number Mr. Borrow's "Lavengro" is dismissed as "a wild original book to be announced rather than dwellt upon", and poor Miss Martineau is roundly abused for lack of tone and taste, in a work which "is a steeplechase after truth most painful and offensive!"

It is significant that the editress treats as a pretty episode an account of "A Morning in Spitalfields", where "early on Monday and Tuesday mornings it is usual for numbers of children to assemble at an appointed spot under the supervision of a policeman, to be hired for the ensuing week. It is a miniature statute fair conducted with the utmost gravity. Girls of nine or ten years old undertake to clean, wash, and nurse children, and to cook for a family, at 1/- to 1/2 per week, no food. It is amusing yet touching", so she prattles on, "to watch these little creatures as they bargain away their services on the best possible terms". She adds that it would be a charity to take a promising little maiden and teach her as well as employ her, but neither she nor her readers seem to have done much about it. They are more interested in an account, in Vol. II, of the Ladies' Westminster Committee which met at Stafford House at the invitation of the Duchess of Sutherland to consider the best means of forwarding the objects of the Great Exhibition.

The editress has a grievance here. She complains that should half a dozen women of sense and spirit form themselves into a ladies' committee some men will at once show up Mrs. —— and Miss —— met together in what is called a most business-like way sitting at a table covered with green baize "engaged in an animated scold". It was really too bad! "But", she alleges stoutly, "when they have had their joke and drawn their caricature, and are out of breath with manly merriment, there sit the Ladies still!" Alas! When they had passed a Resolution inviting the assistance of the Women of England "to further a design in which womanly skill and ingenuity must occupy so distinguished a position" three gentlemen were appointed honorary secretaries. Shame!

No, the readers of the "Ladies' Companion" really preferred a sly article on "How to Manage a Husband", or, better still, instructions on how to make a Coiffure Italienne with green silk leaves and loops of rose-coloured ribbon. Or they enjoyed Geraldine Jewsbury's serial "The Sorrows of Gentility", or, with better taste, Mrs. Gaskell's "Mr. Harrison's Confessions", a faint foreshadowing of "Cranford".

Mrs. Gaskell was probably more in tune at this time with her friend Mrs. Jameson, whose book of lectures "The Communion of Labour", advocating the sharing of the world's work by the sexes, was also on her shelves. Mrs. Jameson pleads for "the importance, religious and practical, attached to the study of physiology for women", and deprecates the masculine view that "a female wishing to know something of those natural laws by which she lives and moves and has her being is to be suspected of a depraved imagination". Mrs. Gaskell's friendship and admiration for Miss Nightingale, who may have been the model for the noble-hearted Margaret Hale in "North and South", must have helped to put her completely in sympathy with this point of view.

"Howitt's Journal", which published two early and depressing stories by Mrs. Gaskell, must certainly have been more acceptable in her immediate circle. It discussed Capital Punishment, Temperance Reform, and the Habits of the Sand Wasp, was liberal-minded on George Sand and Wm. Blake, and published a translation of Andersen's "Red Shoes" for its child readers. Its literary notices were curt and objective. On a new novel,

"The Cardinal's Daughter", it printed one line, "What an indecorous title!"

We all know that the joint Gaskell venture which opened in "Blackwood's" in January, 1837, was "spoken near a dogrose", and that the first number was the last. This sentimental narrative poem, the first of a projected series, "Sketches Among the Poor", can be read in the preface to "Mary Barton" in the Knutsford edition We may guess that the newly-married Elizabeth wrote with feeling

> "Farewell to dusky streets and shrouded skies,
> Her treasured home should bless her yearning eyes,
> And fair as in the days of childish glee
> Each grassy nook and wooded haunt should be"

but we suspect Mr Gaskell of

> "Yes! angel voices called her childhood back
> Blotting out life with its dim sorrowy track'

"Howitt's Journal" and the "Ladies' Companion' gave Mrs Gaskell scope for both the serious and lively, and after the success of "Mary Barton" and "Cranford" she was quite at home in "Household Words", with its earnest flavour, small print, and stress on philanthropic interests Her close neighbours in its double columns were statistics of child health and new education schemes for the poor But the strain of serial publication was uncongenial and inconvenient to her mellowing talent and busy family life She was very loth to be caught up again into Dickens' subsequent venture "All the Year Round' Her last and finest works came out under her own name in "Cornhill", and in its dignified pages she reached the zenith of her career The separate parts are filed, and can be read as they appeared "Harper's", "Fraser's", "Macmillan's" and the Dublin University Magazine each published an article or story of hers But except for "Macmillan's" they must be consulted in the Reference Library

Works of the Rev Wm Gaskell

William Gaskell's literary output is represented here by hymns, sermons, and verse, light and heavy, and by his two lectures on the Lancashire dialect Here also is a review of his lecture on Crabbe, given to the Eccles Literary Society on March 9th, 1872, at which a large and "respectable" audience was present.

His appearance in the pulpit is described and his preachin commented upon by John Evans in "Unitarian Worthies". We may read that at 42 he was slender and pale, his expressive dark eyes flashed, and a pair of bushy black whiskers almost met beneath his chin. Mr Evans speaks of his popularity and eloquence, and calls him a noble Christian character, and a good Samaritan in the truest sense of the word Twenty-one of Mr. Gaskell's sermons, each one printed and bound separately, have been preserved, together with a number of lectures on religious topics, addresses to students and Sunday School workers, and open letters to other Unitarian ministers The titles show a breadth of view unusual for the period, but indicate also strong principles strongly maintained As a young man, in 1836 he began boldly with "Protestant Practices Inconsistent with Protestant Principles", and "Some Evil Tendencies of Popular Theology", but in 1844 he was preaching on "Eternal Salvation not Dependent on Correctness of Belief", and in 1853, indignantly, on "The Injustice of Denying to Unitarians the Christian Name" In 1858 his funeral sermon for Sir John Potter, ex-Mayor and M P, was "On the Duties of the Individual to Society", and for the last of his sermons to be printed he took for his theme "The Investigation of Religious Truth" Two discourses composed for special occasions give a taste of their general quality. On September 8th, 1861, he addressed the meeting of the British Association for the Advancement of Science on "God's Witness to Himself in the World", and spoke finely of Christianity as "too great and noble to be cooped within the narrow walls of a sect, but free to the universe, and having affinities with everything lovely".

In "A Time of War and a Time of Peace", given at Cross Street on May 4th, 1856, on the occasion of the Thanksgiving Service for Victory in the Crimea, he speaks of an honourable war crowned by an honourable peace, defends it as a war of civilization against barbarism, and compares it with the former peace of slavery, exhaustion and despair. "Fighting is bad", he says, "but national dishonour is worse", and, characteristically for the place and time, does not forget to point out the benefits to the nation's trade which will result from the opening of the Black Sea. He sent a copy of this sermon to Mr. Brontë at Haworth, and the old gentleman's letter acknowledging it

and approving its sentiments is one of the Library Treasures. In a very long sentence he writes of his disgust at "the sophistical arguments of an ignorant and knavish class of men who would establish the tyranny of the wicked over the righteous and introduce a chaos of licentiousness into the world". He also wonders how Mrs. Gaskell is progressing with "her mournful but interesting task" and sends most respectful regards to her.

Mr. Gaskell's public work was dignified and useful, and his literary reputation stood high, "the elegance and lustre of his readings" being generally acknowledged. There is evidence of this in the report of the proceedings at the Soirée which was held in the Town Hall on October 15th, 1878, to commemorate the jubilee of his ministry at Cross Street. On that occasion the Literary and Philosophical Society, of which Professor Joule was then President, presented an address, and Professor Roscoe proposed a Resolution embodying cordial congratulations, and "a warm sense of the unwavering interest which this friend and coadjutor has taken in the prosperity of the Society during a membership extending over more than 38 years, during 21 of which he has been a Member of the Council".

The rare fifth edition of "Mary Barton" contains his two lectures on the Lancashire dialect They were published separately in 1854, and the tiny volume is included in the Collection. Considerable research must have gone into its making. The author traces many current words to their Welsh or Norse roots, and draws on his own youthful recollections in explaining their modern usage, e.g. he instances Henry V's kecks (Welsh cecys), the wild hemlock stalks, for as a boy he had used a hollow "Kecky" for a pea shooter, and a playfellow of his remembered taking part in a "stang riding" (A.S. steng-a pole) when a scolding woman's name and misdeeds were rhymed round a village by a shouting urchin astride a pole.

There can be little doubt that Mr. Gaskell fancied himself as a versifier. At the opening and close of his literary career he "dropped into poetry", and "Temperance Rhymes"

(1839) and "Cottonopolis" (1882) can both be enjoyed still. "Temperance Rhymes" were by the earnest young minister dedicated thus, on a full duodecimo page and in various type:

To the Working Men of Manchester
These Rhymes
are inscribed
in the Hope
that they may act as
Another Small Weight
on the Right Side of that
LEVER
which is to raise them
in the Scale
of HUMANITY.

And here is an extract:

"Oh, the hours that I have lost
Lingering o'er the maddening bowl.

"Ah! those hours so darkly slain.
Would I had them back again."

"Cottonopolis", with its sub-title "ex fumo dare lucem", is written in the semi-humorous didactic style beloved of the late Victorians, and most of it is well-meaning doggerel,

as "In Cottonopolis I dwell,
And on the whole I love thee well"

the author going on to speak of

"Clouds of smoke, a burning shame!"

and "Market Street at night
Where blazes the electric light."

There he finds a little waif selling papers who guides him to a home in the slums, and in the second half of the poem there follow suggestions for traffic control, with a speed limit in St. Ann's Square, for the abolition of slums and the smoke menace, for music in the parks, for Public Libraries, and for measures to lessen infant mortality:

"Underneath five years of age
Thousands of children quit this stage."

Mr. Gaskell's hymns must have cost him more trouble. They appear in various collections, and two of them, "Death and Sleep" and "Come and Pray", were once much used.

He had a slight but real lyric gift, and Mr. Evans speaks of his fervency, feeling, and musical expression. A specimen couplet is :

> " Fearless now we rest in faith
> A holy life makes happy death."

Like so many of his contemporaries he shows a strong pre-occupation with Death in most of his compositions. Other hymns, and especially one designed for the close of Divine Service, are more cheerful, and some have quite a revivalist ring, as in

> " Happy, happy, happy Day !
> See the Death clouds melt away ! "

There is ample evidence of the high regard in which he was held by his fellow citizens. At the Jubilee Ceremony when a Scholarship in his name was presented to the students of the Home Missionary Board, a member of his congregation referred to " Your faithful work in the cause of education, your devotion to the principles of civil and religious freedom, and the kind and genial spirit of courtesy and charity which have won you a high position in public estimation, and have beneficially influenced all who have been associated with you ".

Many years before, in a letter to Mrs. Gaskell, the mischievous Jane Carlyle had sent him a mocking little message which hints at the tone and temper of his personality. " Love ? Oh dear, no, it was affection . . . affection then, and respect to Mr. Gaskell ".

But his wife has the final word. " Sylvia's Lovers ", the book which cost her most in effort and study, and which she regarded at the time as her most serious contribution to literature, bears this inscription :

This Book is Dedicated to
My Dear Husband
by Her
Who Best Knows His Value.

Autographs and MSS.

An interesting item in this Section is a photographed copy of the Certificate of Marriage solemnized in the Parish of Nether Knutsford between William Gaskell and Elizabeth Cleghorn

Stevenson, on August 30th, 1832 But the real Treasures of the Collection are autographs and MSS in Mrs Gaskell's own beautiful flowing hand, two of Charles Dickens's letters, some fragments in Mr Gaskell's handwriting, and the letter from Mr Bronte commenting on the Crimean sermon which has already been mentioned There are also four manuscript Music Books, and an old Atlas

Two of the letters are written to James Crossley, and demonstrate Mrs Gaskell's antiquarian and humanitarian interests In one she asks on behalf of a friend who is compiling a book of lectures, for "any curious family (Egerton) traditions and old facts about the dear little town" (Knutsford) and in the other she pleads the cause of a poverty-stricken old lady who writes very dull historical romances

Of greater interest to modern femininity is a charming letter to Mrs Fielden of Smallwood in which, with an almost angelic magnanimity, Mrs Gaskell discusses the engaging of a cook, Ferguson by name, whom she would like to interview, "if you can spare so valuable a servant even for a day' "I think", she continues, "I need not go through the form of asking for Ferguson's character, as the regret you express at parting from her tells me sufficiently what she is", then, quaintly, "I will gladly allow her to go to church", and, a dream-like glimpse of a well-run Victorian household, "we have five women servants (one a "waiter"), and an out-of-door man" "And", she concludes magnificently, "if you and she ever wish to come together again I will gladly agree to it and try to do the best I can in other ways"

A letter from Charles Dickens written from Tavistock House on December 6th, 1852, refers to a ghost story ("The Old Nurse's Story'), which was Mrs. Gaskell's contribution to the current Christmas number of "Household Words", and in which he had suggested some slight alteration "Pray, don't", he begs, "in any corner cupboard of your mind put any least doubt or disparagement of the story I have read it carefully . with great interest. . . . I quite see the difficulties you suggest"

In effect he, the Editor and great literary man, is trying in kindly terms to soothe the Little Woman, to pacify that unaccountable thing the female author. It must have annoyed Mrs. Gaskell very much!

The most important MSS. are a sheet from the Brontë life, and 45 azure folio pages bound in morocco, gold tooled, which form part of the MS. of "Crowley Castle", first published as Chapter I of Dickens's "Mrs. Lirriper's Lodgings" in "All the Year Round". Chr. Number 1863. It can be seen in this form in a bound volume, and is included as such in the chronological list. The MS. was exhibited in 1945 with the Dickens letter. It is hard to avoid the suspicion that this tale was a "pot boiler". It is an unsuccessful blend of Mrs. Gaskell's two styles, the domestic and the sensational, and contains the germ of the plot of "Wives and Daughters". The characters and vicissitudes of the cousins Bessy and Teresa foreshadow the loves and adventures of Molly and Cynthia in their creator's last book. The writing is composed and clear, the spelling sometimes a little erratic, e.g. differenteal.

A fine specimen signature accompanies two verses of Tennyson's "In Memoriam" which Mrs. Gaskell transcribed for the autograph book of Mrs. G. Linnaeus Banks, the authoress of "The Manchester Man".

Oh, yet we trust that somehow good
Will be the final goal of ill. Etc.

The choice of these lines is perhaps significant; they might almost be taken for the motto of Mrs. Gaskell's philosophy of life.

There is one more letter of purely personal interest, written by Mrs. Banks herself in 1878, thirteen years after her friend's death. She was soliciting Mr. Gaskell's patronage for the publication by subscription of a book of verse: "Ripples and Breakers"; "more mature", she claims, "than 'Ivy Leaves', which I gave to Manchester in my unripe years". She speaks of the debt she owes to the Cross Street Library. "I had read all Miss Martineau's 'Illustrations of Political Economy' before I was fourteen. As for Josephus, the big volumes were too heavy and dusty, and I had to leave them perforce where others left them." This infant bluestocking did not grow into a poet, but kind Mr. Gaskell evidently helped her; the letter was found inside the cover of his copy of "Ripples and Breakers".

More recent acquisitions from Plymouth Grove, not catalogued by Mr. Green, are the family Atlas and the Music Books. The Atlas, if not quite a treasure, is certainly a curiosity. Printed in 1799, massively bound, and beautifully engraved, it was an

heirloom in the Holland family. It must have been a feature in the education of several generations of Hollands, Stevensons, and Gaskells. It describes itself as " a Collection of Maps of the World. . . . its Principal Empires, Kingdoms, etc. . . . correctly delineated ", and shows " France divided into provinces agreeable to the decrees of the National Assembly, Germania divided into circles, Poland with its dismembered provinces ", and a very large blank patch with speckled borders which is designated " a new and accurate map of Africa, c. 1794 ". (Perhaps this same map inspired Roger Hamley's voyages of exploration in " Wives and Daughters "?) The study of Geography is presented in attractive terms as " of all the Sciences one of the most pleasing, and at the same time most useful ; it is the almost universal concern ; persons of every rank and situation in life are more or less interested in it, and reap advantage from an acquaintance with it. . . . The serious mind will hereby discover unnumbered proofs of the wisdom, power and goodness of the great Creator, and to the naturalist it opens sources of amusement that are inexhaustible. . . . It has always made a part of polite education. . . ."

Finally, the Music Books. The first and smallest, which is almost a notebook, has already been mentioned. Here indeed is an opportunity to study one facet of a bygone educational system. The Misses Byerley were not nieces of Josiah Wedgewood for nothing. There is evidence of a liberal culture and a pretty taste in elegant verse. But was the choice dictated, or did Elizabeth, at fifteen, make her own selection ? First, in solemn vein, is " The Cypress Wreath, copied from Miss Lord ", "Auld Robin Gray ", Mollie Gibson's favourite, and the eternal " Blue Bells of Scotland ", which were even then jangling. A naughty little French song about " amour " and a " trompeur " has been copied by Sara Buffy, and to make up for it, " Where are the dead, the pious dead, Who walked this world in Christian faith, etc. " But " Ça m'est égal " and "Away, away to the mountain's brow ! " go the Misses Byerley's young ladies in a fine galopade.

It must be possible to trace a tolerably truthful outline of Elizabeth Stevenson's early years between these lines and spaces. Obviously, volume by volume, the music books accompanied her at spinets and pianofortes in London, Knutsford,

Newcastle and Edinburgh, where she was so much admired in her youthful bloom, and finally to Manchester, and on into family life.

The second volume is still the property of Elizabeth Stevenson, now domiciled at the Heath in Knutsford June 12th, 1827. It starts off devoutly with the CIVth Psalm and the Old Hundredth, but soon, "Merrily, merrily ring the bells", and a varied selection of saucy ballads follows. But a more serious influence was supervening, and now we find Handel's lovely "The Heavens are telling the Glory of God" and "Look ye, Saints, the sight is glorious", interleaved, I must admit, with waltzes and cheerful variations, including a robust march in fashionable "Imitation of a Band of Music at a distance" from the Portuguese, and a lazy Spanish air, "Wake, dearest, wake". Now a discreet flavour of intellectual piety pervades the pages, but only briefly, if frivolity fades out, innocent gaiety breaks through "Smile again, my bonnie lassie" is copied in another firmer hand, so is a manly Cossack's song in the original German with careful instructions as to notes "in parenthesis" to be put in or left out, according to the words of the several verses And here on the same sheet as the "Death of Llewellyn" is a faint pencil note at the foot of the page "May I go with you somewhere to have you to myself?" Someone was almost certainly "turning over" for her Could it not have been Mr. Gaskell? The hand is very like And does this mark the very moment of his "offer"? . . . But we have no right to look beyond the keyboard.

The later volumes continue their tuneful progress into a wider and more lively field. There are nursery rhymes for the babies, "A Pie sat on a Pear Tree" and "Little Brown Dog", and quadrilles for the girls as they grew up, simple Italian songs (someone else is being educated now), duets, fairy dances, the Lancashire witches quadrille, and the Duke of Reichstück's waltz. And among the last pages a simple setting for some plain verses:

> When time, who steals our years away,
> Shall steal our pleasures, too;
> The memory of the past will stay,
> And half our joys renew.

Then talk no more of future gloom,
Our joys shall always last.
For hope shall brighten days to come,
And Memory gild the past.

These Music Books have possibly little actual value, but they are in their own style Treasures of the Collection. They enshrine in a peculiarly happy way the traces now left to us of a life that was happy, harmonious, and twice blessed, although lived in an age that had much that was sordid and graceless about it.

Besides the legacy of humour and goodness bequeathed to us in her literary work, we may be grateful, too, for the pleasant echo that lingers in these tired old volumes, for it has the same serenity and sweetness that must charm anyone who explores the Gaskell Collection in the Central Library.

Criticism.

I should like to conclude with some brief notes on the very interesting accumulation of cuttings from literary reviews which is filed on the lower shelves. It can be considered in three parts, viz. : (*a*) contemporary criticism, (*b*) early 20th century opinion, (*c*) modern literary judgment.

Under (*a*) " Mary Barton " comes in for the first blast of the trumpet. It is attacked by the British "Quarterly" (February 17th, 1849) in a level-headed but cold-hearted notice (" the labouring population of Lancashire have met with a somewhat disproportionate amount both of attention and compassion "), and over-praised as " a poem in prose " by the " Prospective Review ", which speaks of " fountains of mirth and sadness " and " the difficulty of reading it without tears ". The " Eclectic Review " also indulges in extravagant praise, calling it a Christian's task, an angel's mission, and a masterpiece of this kind of writing, and while it points out faults in construction and style, acknowledges its life, passion, and pathos, and a fine balance of mind in the writer.

The "Quarterly" provides the most interesting, because the most detailed examination of her position. It accuses her of painting a most doleful and alarming picture ; declares scornfully that " the work is too much in the melodramatic style to be consistent either with probability or good taste ", and unkindly hints at a

" spurious sympathy and the luxury of an imaginary compassion ". It quotes the low rate of accident statistics in support of its contention that the author shows dishonesty or sheer ignorance, uses the hoary and unsound argument that the unthrifty working man is his own worst enemy, and shuffles away from the issue by stating that Manchester is not the best place in which to review the working of the results of the factory system, as it is a commercial rather than an industrial city. While the writer concedes graphic power, and the " delicate touch of a female hand in the love story", he deplores "vague ideas of a levelling and communistic character", argues that young women going out to work at dawn seem to like it, and that the point about child labour is that it should not spoil the market for their fathers.

In April the " Edinburgh " provided less rancorous and more sober and effective comment, pointing out that the book should not be regarded as a mere novel, but insisting that the masters had been misrepresented, and drawing attention to the utter ignorance of the working man of the first principles of economics.

Economists and employers were, of course, angry and aggrieved, and Mrs. Gaskell much later (1876) was soundly rated by W. R. Greg in his " Mistaken Aims and Attainable Ideals of the Artizan Class " ; even he had to admit, however, that " her dialogue has a high degree of naturalness " and that " there is truthfulness in the delineation of individual scenes ". He made up for this concession by pronouncing on the " false morality of lady novelists " in speaking later of " Ruth ".

But the best of her contemporaries took her seriously, following Carlyle's lead, and like Dickens were " profoundly impressed ", until the "Manchester Guardian" growled out a reference to " the morbid sensibility to the condition of factory operatives so fashionable of late among the gentry and landed aristocracy ". Reverberations of the conflict are even now not far distant ; in 1907 the L.C.C. banned " Mary Barton " from school libraries.

Then anxious Nonconformity burnt "Ruth" in spite of "Bentley's Miscellany" of 1853, which called it " one of the saddest tales that have ever stirred gentle hearts and moistened soft cheeks with tears", and said that " no nobler exhortation to charity can be conceived ".

If she had not been a woman of courage, Mrs. Gaskell's heart might have failed her, and, certainly, the further hullabaloo about the Brontë life did stay her pen for a time. But G. H. Lewes eventually called this biography "a piece of the true religion of home", and she would surely have liked to hear Mr. Morley, speaking on Free Trade in 1903, recommend her "most interesting and agreeable fiction to those who did not like Blue Books but wanted the true facts about conditions in Lancashire before 1846". Perhaps the clamour amused her, too. There must have been something of Robin Goodfellow, even (to speak respectfully), of the Fat Boy, in the demure Mrs. Gaskell.

At the time of her death her vogue was a little outworn. When her obituary notices appeared so suddenly and sadly in 1865 they were naturally personal tributes rather than literary reviews, and were not specially remarkable for penetration.

"Her own life the best of her books" (Norton), "Doubt not that her work will do much good in the future" (Payne) are typical of many. But the "Pall Mall" said wisely: "Her books are a picture of the good English life and sound English manners beyond the incidence of class and fashion". Her funeral sermon, preached by the Rev. James Drummond on November 19th and entitled "The Holiness of Sorrow", was rather an exhortation to those left behind than a tribute to her achievement, though he did speak of the influence of her kindly and unworldly thoughts (Mrs. Gaskell would have liked that), and "the genius which has conferred happiness upon so many".

As the century closed and the centenary of her birth approached fashion began to veer. The generation which had found inspiration in her sociological novels, and delicious thrills in her "horrid" stories, and who later had chuckled over "Wives and Daughters" and sighed for Cousin Phillis, gave way to a younger set which had a friendly admiration for the delicate charm of "Cranford", but ignored the more mature novels with their unfamiliar settings and out-of-date idiom. Mrs. Gaskell was classed as the Brontë biographer, and few troubled to taste the artistry and subtle truth of her later books.

Clement Shorter admitted this in his Centenary article for the "Glasgow Herald", for he foretold a revival of popular recognition and advised "investigation by some wide reader or curious explorer in the byways of literature".

In her Centenary year faithful friends and devoted admirers still spoke for her, but serious appraisal was now added to affectionate appreciation. Some critics were more generous or more acute than their fellows. The "Fortnightly", which in 1878 had tried to damn faintly with "a high place among the comparatively unambitious", now made amends over the signature K. L. Montgomery, "Will live again in minds made noble by her presence". Lewis Melville in the "Nineteenth Century" was depreciatory, "An indifferent novelist . . . stands or falls by 'Cranford', so pathetic, tender, and delightful". "A book to be loved" was "Chambers's" verdict. "Cornhill", as was fitting, had three articles, including a distinguished contribution by the Master of Peterhouse. The "Nation" was vague and a trifle contradictory: "The characters have no inner history . . . it is a world of the pure in heart". The "Scottish Co-operator" called her roundly a wise, good woman. The "Manchester Guardian" provided two excellent notices; one a biographical study by Flora Masson, the other a critical review by C. H. who speaks of "her classic quality, her humanity and humour, the fine flower of her good sense, rare sympathy and insight". He maintains that she had "the true comic spirit, urbane, lucent, and cool, so rare in women", and compares her to Goldsmith, Lamb, and even to Jane Austen. This last comparison is made several times by various critics. Christobel Coleridge in "Great English Characters in Fiction" compares Mollie Gibson to Fanny Price and Anne Elliot, and not to their advantage.

Among the modern critics "Q" is pre-eminent. His just tribute sets the seal upon Mrs. Gaskell's reputation. "This noble woman", he writes, and speaks of "Cranford's pawky fun" and "the sunset softness of Cousin Phillis". He compares her work to all that is best in Theocritus, claiming that it is elementally of the best literary breeding, the rural scenes "English yet pure Virgil", and at times written in a "prose that shimmers with beauty".

But none of these critical people seem to have noticed a small thing. In Chapter 13 of "Wives and Daughters" dear strict Miss Browning's name is Clarinda; halfway through the book, in Chapter 47, she has changed it to Dorothy, and no one says a word! Strange incident in so conservative a place as

Hollingford! But if its creator had been spared to hold the bound volume in her hand she must have corrected the slip, so it has poignancy for all who love her.

Harper Bros.' paper-back edition of "Cousin Phillis" (1864) has an amusing notice of Trollope's "Rachel Ray" from the "London Athenæum" among its advertisements. It speaks of his delicate delineation of female character, and calls the women of his tale admirable, "they are honest flesh and blood, just such perplexing, provoking, self-denying lovable creatures as fathers, husbands, brothers and lovers alternately rail at and laud to the skies" What a relevation of the Victorian masculine mind! And so much for Mrs. Gaskell's efforts as an artist, to present her sex simply and truthfully as rational creatures in everyday life. It is interesting to look back to this pronouncement when we consider the company of young Englishwomen whom she created for our delight with such subtle sympathy, while so many of Mr. Trollope's young ladies are merely fashion plates in pretty crinolines.

Mrs. Gaskell herself was very modest about her work. Her early-expressed ambition had been to write like Crabbe, but in a more "seeing-beauty" spirit. After the painful consequences of her Brontë indiscretions she was willing humbly to accept the unfeeling dictum of the American publisher Underwood, who warned her that "writers of the second class" could not hope to please the mercurial Americans with their semi-alien culture.

She knew good writing when she met it In a letter to Charles Norton in 1857 she had written delightedly about "Scenes of Clerical Life" "a discovery of my own. . . . I haven't a notion who wrote them"; and wistfully, two years later: "It is not worth while trying to write while there are such books as 'Adam Bede'." Yet George Eliot herself, in a letter of which a photographic replica was included in the 1914 Exhibition, wrote gratefully of her consciousness that "my feeling towards life and art had some affinity with the feeling which inspired 'Cranford'." In passing it is of interest to compare the two signatures, George Eliot's close, clever hooked writing with its downward curves, and Mrs. Gaskell's beautifully even and rounded script so characteristically clear and calm.

Mrs. Ritchie writes that Mrs. Gaskell took grim subjects for humanity's sake rather than art's; and yet after her early excursions into the romantic and the macabre she would seem to have found herself in treating the real drama of the Brontës' life. Her powers were at full stretch in recording the struggles of these fireflies in the web of domesticity. She worked hard over "Sylvia's Lovers", studying for the truth as Dickens did in composing "Hard Times" and "A Tale of Two Cities", but with much the same result, a lack of spontaneity, and a stiffness in the fibre of the story. Her art came to perfection when she was content to be the chronicler of the innocent agony of Phillis Holman, and the sublime machinations of Mrs. Gibson.

From "Drumble" in the early days she had seen "Cranford" and its little people through a silver haze, but when the mist of the ideal had cleared, the real world of "Hollingford" emerged, exquisitely distinct in the mellow autumn sunshine.

Note. Extracts from MSS. and printed matter, the property of the City of Manchester, are included here by kind permission of the City Librarian. I wish also to thank the Staff of the Central Library for their unfailing courtesy and patience, and most particularly the Librarian and Staff of the Special Collections whose help and wise advice have been quite invaluable to me.

The Hough,
Wilmslow.

Natural Law.

By A. R. Vidler.

In Fielding's *Tom Jones* Thwackum, conversing with Square, says: "The law of nature is a jargon of words, which means nothing. I know not of any such law, nor of any right which can be derived from it. . . ." To which Square replies: ". . . If there be no law of nature, there is no right nor wrong". It is significant that an eighteenth century novelist could easily introduce a conversation on this subject. The conception of a law of nature was indeed one that was familiar to all educated men at that time. But the traditional conception, at any rate under this name, went out of fashion during the nineteenth century, and the term "natural law" was appropriated by natural science in the sense of "a theoretical principle deduced from particular facts, applicable to a defined group or class of phenomena, and expressible by the statement that a particular phenomenon always occurs if certain conditions be present". (*N. E. D.*)

Perhaps the most striking evidence of the disappearance of the traditional conception is the fact that the articles on Natural Law in the Encyclopædia Britannica and the Encyclopædia of Religion and Ethics are entirely concerned with the scientific use of the term. Even conservative theologians had allowed the conception to lapse, though it retained a place in Roman Catholic text-books. Now, however, it is being revived. Not only has the Pope made a good deal of it in his recent encyclicals, but interest in the conception has been aroused and appears to be increasing among social philosophers in many countries. It is probable that this interest has been chiefly promoted by recognition of the ideological vacuum in the West.

Men who reject the ideologies of communism and fascism are having to ask themselves for what principles they stand. Slogans about democracy, liberty or justice prove unsatisfactory on examination, both because the totalitarians use them too, and because it is apparent that there is no consensus of opinion in the West about their meaning, their ground or the source of their authority. You might expect a theologian to cash in on this situation by urging that the vacuum or confusion of moral purpose in the West is due to the neglect of Christianity, and that all we have to do is to recover Christian principles. Some

Christian propagandists are indeed issuing advertisements to that effect. They see no more need than Parson Thwackum did of the conception of a natural law.

These advertisements will not, however, carry conviction to considering men. For, first, apart from an inconceivable miracle, a general and immediate revival of Christianity or of a Christian civilisation in the West cannot be regarded as within the range of possibility. Whereas our need is general and immediate for something which will serve to define the common moral purpose of all who want to preserve the way of life and the standard of values that have been traditional in the West; for something, that is, which will command the assent not only of Christians, but also of Jews, and of liberal humanists, and of men of good will, and so forth. Might not natural law serve this purpose?

But, secondly, when we inquire what are the Christian principles for man's social life, we find that modern Christians have no satisfactory answer to propound. It has been their custom to talk about Christian principles and ideals in so vague and abstract a way that they fail to bear upon our actual problems. The assertion that "if only all men would live as brothers all would be well", or apostrophes about the ethics of the Sermon on the Mount get us nowhere, and it must be confessed that for too long Christian orators were content to put out stuff which boiled down to that in the end.

And, thirdly, it is happily the case that a growing number of Christian thinkers are coming to recognise that that sort of thing will not do. They are inquiring whether their faith has not some better resources upon which to draw. They are realising that in the palmy days of Christian civilisation, in so far as there ever were any, it was held that the law of nature ought to govern man's social behaviour. They are realising that the Church accepted and preserved the Greek and Stoic conception of natural law, and that this was an essential part of Christian doctrine, so essential that there was never any serious controversy about it. Nor was this an assimilation of something that was alien to the teaching of the Bible. The Bible presupposes and affirms the law of nature as part of the law of God. It was held that the authority of the law of nature could be acknowledged and was acknowledged by men who did not consciously acknowledge the authority of Moses or of Jesus Christ. Thus theologians, both

Catholic and Protestant, are now engaged in unearthing this conception which they had allowed to be buried or disregarded, and are trying to discover how it can best be revivified.

My own interest in the subject is from this angle, but since one of the main attractions of a doctrine of natural law is that it may provide a common standing ground not only for separated Christians but for non-Christians too, I am anxious to hear it discussed from every possible point of view. The conception of natural law is part and parcel not only of the Jewish-Christian and European tradition, but particularly of the English tradition. Although here also the tradition has been lost sight of, if not abandoned, it used to be held that the Laws of England are founded upon the law of nature (as well as upon the revealed law of God). The best way of starting an inquiry whether the traditional conception can be revived may be briefly to summarise what Blackstone says about it at the beginning of his *Commentaries on the Laws of England.*

Law, he says, in its most general and comprehensive sense, signifies a rule of action, and is applied to all kinds of action, whether animate or inanimate, rational or irrational. It is that rule of action, which is prescribed by some superior, and which the inferior is bound to obey. When the supreme being formed the universe, and created matter out of nothing, he impressed certain principles upon that matter, from which it can never depart, and without which it would cease to be. In those creatures that have neither the power to think nor to will, these laws must invariably be obeyed. But man is a creature endowed with both reason and freewill. When God created man he laid down certain immutable laws of human nature, whereby man's free-will is in some degree regulated and restrained, and gave him also the faculty of reason to discover the purport of those laws. The creator, since He is a being of infinite wisdom as well as of infinite power, has laid down only such laws as were founded in those relations of justice that existed in the nature of things. ("The being of God", said Hooker, "is a kind of law to his working; for that perfection which God is, giveth perfection to that he doth.") This law of nature, being coeval with mankind and dictated by God Himself, is superior in obligation to any other. It is binding over all the globe in all countries, and at all times: no human laws are of any validity, if contrary to it, and such of

them as are valid derive all their force and authority, mediately or immediately, from this original.

Blackstone goes on to say that if man's reason were not corrupt the task of discovering the law of nature would be easy and pleasant; but because man's reason is corrupt, God has by a special revelation made known the essential precepts of the law of nature. This is known as the law of revelation. Thirdly, there is the law of nations. "As it is impossible for the whole race of mankind to be united in one great society, they must necessarily divide into many; and form separate states, commonwealths, and nations, entirely independent of each other, and yet liable to a mutual intercourse." The law of nations arises to regulate this mutual intercourse, it depends entirely upon the rules of natural law or upon mutual compacts, etc. He then proceeds to deal with municipal or civil law, i.e. the laws of particular states.

The law of nature, with which we are concerned, is the law of *human* nature. It is distinguished from the eternal law, from which it is derived; from the revealed law which makes known some of its precepts; from the law of nations, by which the law of nature is applied to the regulation of the intercourse of nations; and from the positive law of particular states. Another distinction of some importance is that between (what Troeltsch termed) the absolute and the relative laws of nature. This distinction was drawn by the ancients; the absolute law of nature being that which was applicable to man in a state of innocence, and the relative law of nature that which was applicable in the state of corruption. Thus the Christian Fathers accepted the Stoic view that coercive government and slavery were contrary to the absolute, but in accord with the relative, law of nature. This distinction corresponds to that which a theologian would draw between the law of creation (Adamic) before the fall and the Noachian and Mosaic law after the fall, though a good deal of confusion surrounds this distinction, and it is further complicated by the delivery of the new law of Christ.

The fundamental question is whether we can still hold that there is a law of human nature, i.e. a rule of action for human beings, of universal application and obligation. If there is not, are we not embarked upon a sea of sheer relativism? If there is, whence is it derived? How may it be known? What is its

content? The traditional doctrine affirms that it is implanted in man by the Creator. It supposes that the human being has a specific and permanent structure or character, and that the law of nature is the pattern of behaviour appropriate for him. It does not consist of arbitrary dictates, but corresponds to his nature, and his conscience testifies to it. Therefore, apart from a supernatural revelation, man can to some extent discern it by reflecting upon the nature of his own being. It did indeed seem in the past that all men everywhere perceived a distinction between right and wrong; the dogma of the fall was thought to explain why this perception varied both in degree of clarity and in what it certified. But it is a question how long the claim can be sustained that all men have some perception of the difference between right and wrong, and therein of the natural law, in this age when nihilism and nihilistic tendencies are gaining ground. It would seem that doctrines of natural law have enjoyed their greatest vogue in societies and periods that were comparatively homogeneous and settled, for example, the Hellenistic-Roman world (Stoic), the middle ages (scholastic), and the eighteenth century (enlightenment). Did these Societies project on to mankind in general assumptions which they happened to take for granted or which accorded with their interests? We shall certainly have to allow for the relative element in all doctrines of natural law, but it may be possible to do this and to maintain still that it is in principle absolute and universal. If it cannot be said that nihilism is the tribute which scepticism pays to belief, it does nevertheless appear that nihilism is so destructive of the human being at every level of his existence as to manifest its inhuman character, i.e. its contradiction to the law of human nature.

Another major and modern difficulty arises from the alleged permanence of the natural law. It postulates that the human being has a permanent and unchangeable structure beneath all variations. This may well have seemed so heretofore. But if the expectations that are now entertained in some quarters that by psychological techniques and social engineering it will be possible to produce fundamental changes in human nature, the ground of the natural law will be undermined. Those who acknowledge a permanent law of human nature are bound to believe, although they cannot prove, that such expectations are

not justified, and that attempts to produce a fundamental change in human nature will in one way or another be defeated.

Supposing then that these difficulties can be overcome, or at least that the quest for a natural law is not torpedoed by them at the outset, we have to inquire how it may be known and what is its content, i.e. what is the rule of action that it prescribes? Its traditional expositors, when pressed back, have had to be content with affirming a very general prescription, e.g. that good is to be done and evil is to be avoided. This may imply a good deal, but, if a doctrine of natural law is to be of any practical use, it must produce more definite prescriptions than that. Jews and Christians have the ambiguous advantage of holding that the Mosaic decalogue is a revealed publication of the natural law (with the exception of the command about sabbath observance, which Christians, at any rate, regard as in its form, if not in its substance, a positive law for the Jewish people). "La Décalogue, sauf la fixation au jour du sabbat du repos liturgique . est l'expression claire et solennelle (de la loi naturelle) donnée par Dieu Lui-même".—*Dict. Théologie Catholique.* I say this is an advantage, because it does give the natural law definite content. But it is ambiguous, not for the reason Bunyan had in mind when he wrote: "Have a care thou keep out of the reach of those great guns the Ten Commandments", but because the decalogue seems prima facie, so far from being universal, precisely relative to the polity and conditions of ancient Israel. Moreover, while it gives definite content to the natural law, doesn't it give far too much? It assigns at least as much importance to the precepts of the first table as to those of the second table. It treats the worship of the One God as of the same obligation as the prohibition of theft, for example. This was presumed by traditional exponents of natural law. "In order that any man may dwell aright in a community", said St. Thomas Acquinas, "two things are required: the first is that he behave well to the head of the community; the other is that he behave well to those who are his fellows and partners in the community. It is therefore necessary that the Divine law should contain in the first place precepts ordering man in his relation to God; and in the second place, other precepts ordering man in his relations to other men who are his neighbours and live with him under God".

I have the impression that those who are canvassing a revival of natural law to-day are wont to maintain a discreet silence about the precepts of the first table. They look for a doctrine of natural law which will define man's duty to his neighbour, and perhaps to the subhuman creation (fertility of the soil, etc.), but which will leave man's duty to God on one side. This procedure beheads the traditional formulations of the law of nature, but the reason for it is not far to seek. It may yet be possible to secure a sufficient consensus of opinion in the West about man's duty to his neighbour and even about his duty to the soil, since no one yet denies the existence of that, but it would be impossible to secure a consensus about man's duty to God or whether he had any. We might be able to agree that mankind is a community of persons with mutual obligations; we should not be able to agree that it is a community with a head and with obligations to the head.

This circumstance need not, however, be fatal to co-operation on a basis of natural law. Men who acknowledge the authority of both tables, or their modern equivalents, should still be thankful to co-operate with men who acknowledge only the second table, in restoring health to our diseased society, while men who regard the first table as only a question mark may yet be willing to indulge an overbelief in that respect in their collaborators. For Christians this co-operation will be inspired by more than considerations of expediency or opportunism, since they believe that the whole world and all men are under the kingly rule of God and that He does not leave Himself without witnesses and obedient servants even among those who deny His existence.

Indeed, Christians ought freely to admit that in perceiving the bearing of the permanent principles of the law of nature under contemporary conditions non-Christians may often surpass them in discernment. For in order to determine the prescription of the natural law in any given place or time, conditions that are changeable as well as principles that are permanent have to be taken into account. Christians, because of their concern with the permanent, and because of a proneness to conservatism which has its own value, may be slower than non-Christians, who may sit more loosely to tradition, to perceive the significance

of what is changing. Take, for example, the eighth commandment (Thou shalt not steal)—the natural law concerning property. In a primitive handicraft society the private ownership of his tools gives security, dignity and responsibility to the worker, whereas in a large-scale machine society the private ownership of the means of production places the workers in the power of the owners and deprives them of security, etc. It is notorious that Christians were slower than, e.g. Marxists in perceiving that a change in technical conditions required an alteration in the prescription of the natural law concerning private property.

The truth appears to be that the permanent principles of the natural law can acquire definite significance only when they are expressed in terms of, and brought to bear upon, specific historical conditions. As Professor G. M. Trevelyan has said: " If law is indeed to be the permanent rule of life to a nation, it must be apt to change with the changing needs and circumstances of society". Thus we can never have a formulation of the content of natural law, except in the most abstract terms, which is free from relativity, and therefore from the need of modification in another set of circumstances. This applies to the decalogue and all traditional Christian formulations. Every age has to formulate the natural law afresh, but does it not make all the difference in the world whether it conceives itself to be merely rationalising its own interests or to be acknowledging in the most appropriate form the permanent and universal law of human nature?

It does not, of course, happen that a human society or civilisation or culture starts out with a precise formulation of the natural law or an elaborate social philosophy and then proceeds to apply it. Such formulation or elaboration comes rather at the end of an historical period—it is the fruit, not the seed. But the seed is necessary; it may consist of certain fundamental and latent directives. And it is these that our western society seems at present to lack or to be very unsure of. It is unlikely that they will arise directly out of intellectual discussion. The law of nature would be more likely to start on a new lease of life if someone like Luther were inspired to broadcast some theses that were felt to hit the nail on the head.

Our case is indeed much more complicated than his. We were already perplexed enough. And now we are plausibly told

that in the discovery of atomic power the world has " witnessed an event comparable only to the discovery of fire as one of the great turning points in history, with illimitable potentialities for good or evil ". So says the Report of the Commission appointed by the British Council of Churches on the Era of Atomic Power. If this be so, the fundamental question about the law of human nature is more urgent than ever. The Report states in the following words what this paper is principally concerned to maintain :

" Without faith in a standard of right and wrong, however diverse may be the forms in which it finds expression in different periods of history and different social circumstances, we have no criterion by which to judge what is really in the human interest. Belief in right and wrong is belief in a standard that has not been set by men but exists independently of them, and for that reason imposes on them a binding obligation. This belief can persist only if men are persuaded that they are not wholly involved in the flux of things, but are related to a source of authority outside and above the historical process."

Further Greek Vases in the Manchester Museum and School of Art.

By Professor T. B. L. WEBSTER, M.A., F.S.A.

The occasion for this paper was the return of the Greek vases to the Manchester Museum and the School of Art from their various places of safe-keeping, which coincided with the presentation to the Museum of the late Sir Thomas Barlow's collection; the three most interesting of his vases are here published as nos. 5, 6 and 10 below. The School of Art vases were on loan to the Museum during the latter months of 1945, which made it possible to examine and photograph certain pieces not included in my earlier publication (*Manchester Memoirs* lxxviii, 1f.); they are nos. 2, 13 and 14 below. Two other recent gifts to the Manchester Museum have been included (nos. 1 and 4), two vases on loan (nos. 7 and 9), and two vases which had been in the Museum some time but had not previously been published (nos. 3 and 12). Most of these vases are noticed in *A Guide to the Greek Vases*, Manchester Museum Publications, New Series 3, 1946. The Museum also acquired in May, 1946, two very fine red-figure vases from the Marshall Brooks collection at Tarporley, one by purchase, one from private donors with a grant from the Royal Manchester Institution (nos. 8 and 11); these will be published more fully later. Finally, I should like to express my gratitude to Professor J. D. Beazley for reading my manuscript and making many suggestions.

LIST OF VASES.

1 *Italo-Corinthian aryballos* (pl. 1*a*).

Museum, III C 98. Presented by Emeritus Professor E. Robertson, 1945.

Mouth: broad red band with narrow black band on each side.

Shoulder: tongues separated from picture by two black lines.

Body: panther, bull, and swan with added red; below main picture, black line, broad red line, four thin black lines, red line, two thin black lines.

Late seventh or early sixth century B.C.

Cf. for shape and decoration *C.V.A.*, *Oxford*, III C, pl. IV, fig. 25, 27, 30, 31; *Cambridge*, III C, pl. V, 6.

2. *Attic black-figured amphora* (pl. 1*b*, *c*).

School of Art, Aa 45.

Top of mouth reserved, with graffito (apparently ancient) HE.

Red line on neck above attachment of handles.

Rays at foot.

Lotus pattern at top of picture panels ; red for calyx of lotus.

A. Menelaus and Helen. An old man stands on left holding a spear (red : wreath in hair, beard, folds in cloak, spots on cloak). Menelaus threatens Helen with his sword, she holds her veil away from her face (red : Menelaus' sword blade, spot on chiton skirt ; Helen's eye, stripe on veil, spots on peplos. White : Menelaus' sword-hilt ; dots on crest holder, neck and armholes of corslet, and round the red spot on chiton ; four- and five-dot rosettes on Helen's peplos). A second warrior stands facing Helen (red : centrepiece of comb, greaves, spots on shield rim ; White : dolphin on shield). The old man on the left may be Priam, who is a seated onlooker on the skyphos by Makron ; the second warrior is unidentified both here and in other black-figure pictures, e.g. *J.H.S.*, 1927, 79 (Antimenes painter) ; *C.V.A. Munich*, pl. 22 (Amasis ptr.) ; *B.S.A.*, xxxii, pl. 4 (ptr. of Vatican 365). On another vase, which is extremely like ours, Vatican 358 (see below), the scene is reversed : Warrior, Helen, Menelaus, young man (in same position and clothing as " Priam ").

B. Chariot fight. General scheme as in the Swinger's Rochdale amphora (*Manchester Memoirs*, lxxxiii, pl. 2*a*), but here the warrior leaps from the chariot against his opponent behind the horses. (Red : hair and beard of charioteer, body of chariot, breast-band, manes and tails of two horses, spots on shield and on chiton, greaves of warrior leaping from chariot ; band on helmet, greaves of warrior behind horses ; chiton of dying warrior ; shield-rim, greaves, stripes and dots on chiton of warrior on the right. White : cross straps of charioteer ; crest and dots on chiton of jumping warrior ; dots on helmet of attacking warrior ; crest and spots on skin worn by dying warrior ; tripod on shield of warrior on the right. 550—540 B.C.

Nearest analogy for treatment of clothes, knees, ears, is perhaps Vatican 358 (Albizzati, *Vasi dipinti*, pl. 47) and Cambridge 32 10 (*C.V.A.* fasc. 2, pls. XXII, 2; XXVIII, 1 and 6), which Beazley assigns with London B168 (*C.V.A.* pl. 31, 2) and Louvre F36 bis (*C.V.A.* pl. 17, 4—5) to the Towry White painter. Compare also for profiles and inner markings, the early Andokides painter, Würzburg 184.

3. *Attic black-figured cup* (pl. 2*a*).

Museum, III H 46. From Greece, bought 1935.

Eye-cup shape (cf. particularly the Exekias eye-cup in Munich, Bloesch, *Formen*, pl. I. i.); red plastic ring between bowl and stem.

Dance of satyrs and mænads; dog under one handle.

Mænads have either black peplos with trefoil and quadrifoil white dots and a red belt, or red peplos with black belt; one of the "red" mænads has only her overfall red and red spots on her skirt.

The mænads' profiles are nut-cracker; their eyes are large, the lower lid straight, the pupil red. Cf. Athens 458 (Bloesch, *Formen*, pl. I, 2) for subject. 550—40 B.C.

4. *Attic black-figured cup* (pl. 2*b*).

Museum, III H 53. From Greece, presented by R. M. and J. M. Cook, 1945.

No plastic ring between bowl and foot; high foot as Little Master cup (for this Beazley compares Athens 445, Naples 2740).

Mænads between eyes; youths between eyes and handles; stylised lotus under handles. Red for mænads' peplos, iris of eyes, youths' hair.

Of the eye-cups with lotus under handles (cf. H. R. W. Smith on *C.V.A. California*, pl. xvii, 2), Würzburg 426 has exactly the same ornament under the handles; the figure drawing of *Castellani*, pl. xcix, 7 has some connection with ours and with *C.V.A. British Museum*, pl. 22, 1; *Castellani*, pl. xcix, 8 also connects with Würzburg 426. *C.V.A. Villa Giulia*, pl. 35, 1 and *California*, pl. xvii, 2 stand apart and *C.V.A. Cambridge*, pl xviii, 2 is entirely different. 540—530 B.C.

5. *Attic black-figured neck amphora* (pl. 2*c*, and *d*).

Museum, III H 49. Presented in memory of Sir Thomas Barlow, 1945. Height, 27·2 cm.

Special shape (cf. *C.V.A. London*, pl. 45, 6 and others listed by Miss Haspels, *Attic Black-figured Lekythoi*, 219).

Neck : palmettes (as on London vase quoted).

On both sides, two warriors advancing :

A. First warrior looks back ; he has white dots on crest, white chiton with red lines at top and bottom (cf. Odysseus in Haspels, *op. cit.*, pl. 29, 3), shield with red rim and white maple leaf as charge. Second warrior has white crest, shield with red rim and single white leg as charge.

B. First warrior has shield with red rim and white panther head as charge ; second warrior shield with red dots on rim and three white dots as charge.

Early fifth century. By the Edinburgh painter (see Haspels, *loc. cit.*).

6. *Attic black-figured neck amphora* (pl. 3*a*, *b*).

Museum, III H 48. Presented in memory of Sir Thomas Barlow, 1945. Height, 20·8 cm.

Small, slim neck amphora, with triple handles.

Neck : palmettes with white centres ; groups of four dots in the empty spaces (cf. Haspels, *op. cit.*, 138, on Hæmon ptr. and Pholos group).

Body : careless palmettes on branches growing from under handles.

A. Satyr dancing ; he holds white wreath in right hand.

B. Mænad dancing.

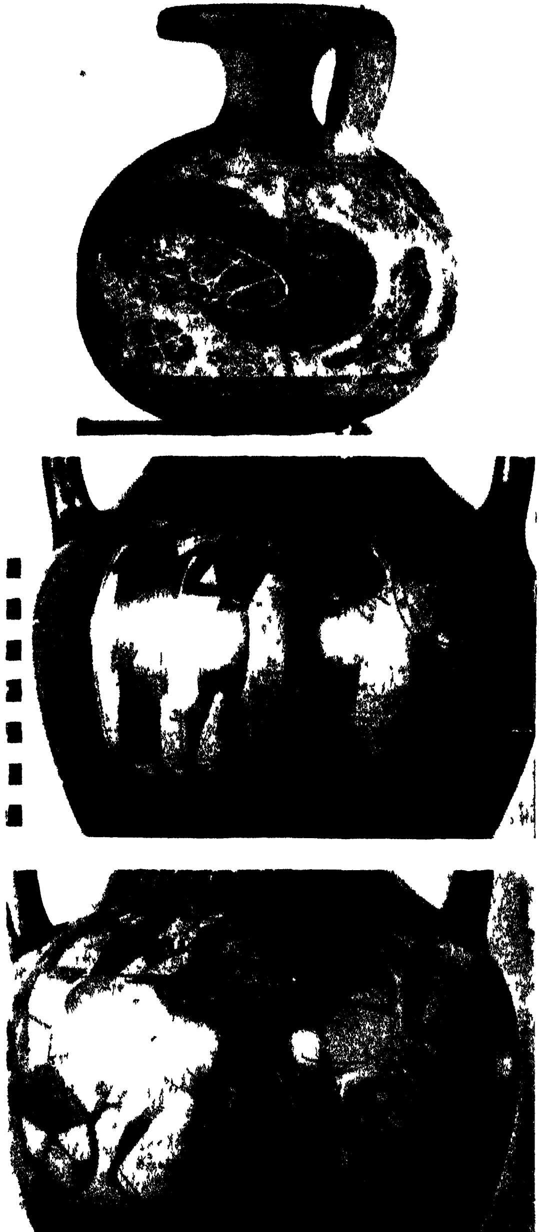
Graffito on foot.

Early fifth century. Style not unlike Haspel's Pholos group

7. *Attic amphora of Panathenaic shape* (pl. 3*c*, *d*).

Museum, III H 52. Bought at Sotheby's, 1943 ; formerly Hope (*Tillyard Hope vases*, pl. 5, No. 27) ; lent by T. B. L. Webster. Height, 30·2 cm.

Neck : palmettes, two upright about one inverted, dots in open spaces ; raised red rim below neck ; stylised tongues above picture. Rays at foot.



a

b

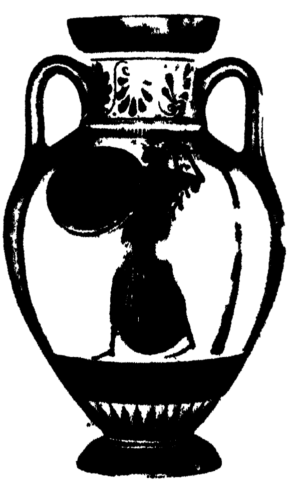
c

PLATE I

c PLATL 2. *d*

a

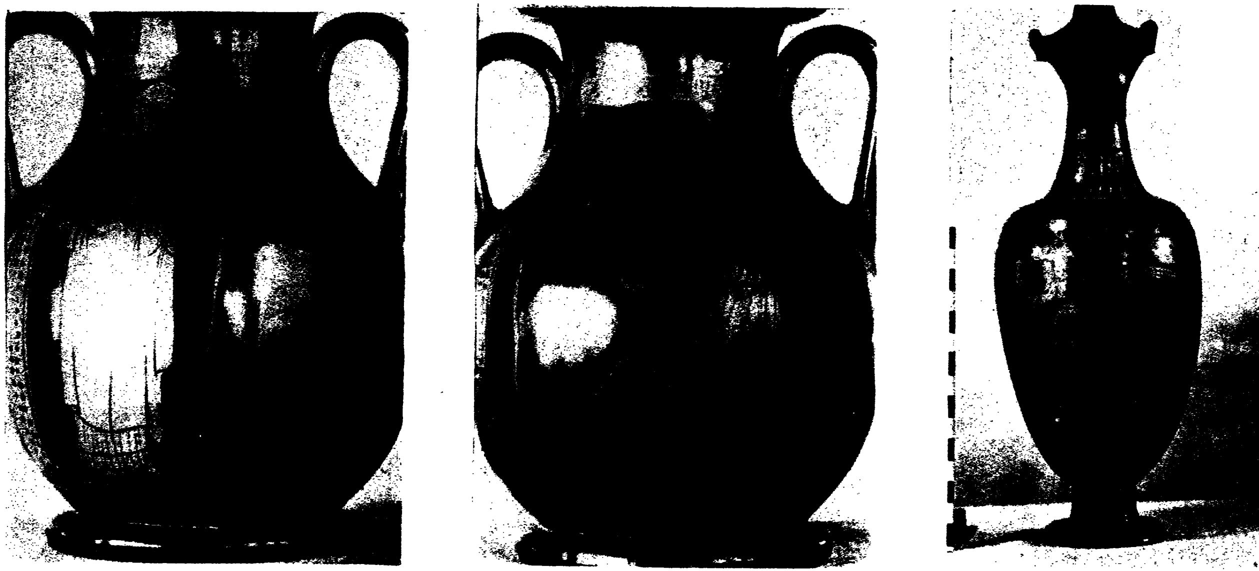
b



d

Plate 3

PLATE 4.



a *b* *c*

PLATE 5.

a

b

c

Plate 6.

A. Athena with ægis, spear and shield between columns carrying discs. White for Athena's flesh (note that the black has shrunk, particularly on face and arms), snake on shield, incised crosses on ægis.

B. Flautist in long loose chiton (traces of white stripe below arms) between two young men in himatia ; the man on the left props himself on a stick under the shoulder and holds a wand (for the single instead of double wand. Cf. Würzburg 204 ; for the gesture cf. Beazley, *J.H.S.*, xlii, 72) ; the man on the right holds a stick.

Early fifth century. The Panathenaics in the University of California (*C.V.A.* fasc. i, pl. XXIII), which Beazley ascribes to the same hand as Oxford 218 B, and Rhodes (*C.V.A.* fasc. i, III Hf, pl. 1) belong to the same time and the same general style. The drapery should be compared with Makron and the Brygos painter for period.

8. *Attic red-figured Nolan amphora.*

Museum, III I 40. Bought at Sotheby's, 1946 ; formerly Marshall Brooks, formerly Hamilton, formerly Biscoe.

Foot modern, large break in the obverse.

Below pictures, mæander and saltires.

A. Herakles and Centaur. Red for Herakles' baldric, blood from wounds in Centaur's flank and hindquarters.

B. Centaur galloping with lionskin over his left arm.

480 B.C. Berlin painter (Beazley, *A.R.V.*, 135, no. 51).

9. *Attic red-figured Column Krater* (pl. 4).

Museum, III I 39. Lent by Lady Barlow. Height, 45·1 cm.

Mouth and foot : rays.

Rim : Ivy leaves.

Neck : Palmette and lotus on front ; nothing behind.

Pictures framed by tongue pattern at top and ivy-leaves at sides.

A. Young man departing in chariot : behind the horses, old man holding phiale, woman holding œnochœ.

B. Old man in himation with stick ; woman with phiale ; young man with stick.

470—60 B.C. Beazley has suggested the Orchard Painter (on whom see *A.R.V.* 346). His column krater in Lecce (*C.V.A.*, pl. 9, 3—4) has the same ivy-leaves on the rim ; again no

neck pattern on the reverse; the great width of some of the cloaked figures, the use of thick black lines to mark the bottom edge and sometimes a falling edge of cloak, the drawing of the cloak behind but not round the boy's head are marks of this painter (cf. also *C.V.A., Bologna*, pl. 28, 1—3; 24, 1—3; *C.V.A. London*, pl. 69, 1; *Coghill*, pl. 12). The tilted clear eyes of the old man and boy on the front and of the old man on the back of our vase recall the Altamura ptr. and early Niobid ptr. The neck pattern recurs with minor variations, particularly on hydriæ of this period.

10. *Attic red-figured pelike* (pl. 5*a*, *b*).

Museum, III I 34. Presented in memory of Sir Thomas Barlow. Height, 15.1 cm.

Framing of pictures: above, short separated tongues; at the sides, double dots between double lines; below, mæander.

A. Two boys in himatia; one with his himation pulled over his head.

B. Boy in himation with stick.

470—60 B.C. Influenced by Pan painter (e.g. Beazley, *Panmaler*, pl. 30), cf. also Manner of Alkimachos ptr. (*C.V.A., London*, pl. 46, 2). Beazley attributes to Painter of London E356, of whose vases he says (*A.R.V.* 593): "Some of these are rather like the Penthesilea painter himself."

11. *Attic red-figured pelike.*

Museum, III I 41. Bought at Sotheby's, 1946; formerly Marshall Brooks; presented to the Museum by four private donors with a grant from the Royal Manchester Institution.

Below pictures, mæander and cross; above pictures, A. laurel wreath, B. mæander and cross.

A. Young man with sword in right hand, petasos on back, cloak over left arm pursuing woman in ungirt peplos.

B. Bearded man in cloak leaning on stick, woman in cloak, column between them.

460—50 B.C. Hermonax (Beazley, *A.R.V.*, 319, no. 29; Johnson, *A.J.A.*, xlix, 491 f.).

12. *Campanian skyphos* (pl. 6*a*, *b*).

Museum, IV E 27, presented by Miss A. E. Barlow.

A. Eros, snub-nosed, white wreath in hair, white wreath round body, white bracelet on arms, white bow in hand, white soles on shoes.

B. Aphrodite, with white wreath in hair and round breast, formal flower in hand, seated upon rock. Under handles palmette ornament ending in formal flower.

Early fourth century B.C. Floral ornament seems to belong to same general family as Beazley's Parrish painter (*J.H.S.* lxiii, 72 f.) : cf. *C.V.A. London*, pl. 11, 9, etc. (cf. also pl. 6, 2*b*). The drawing appears to me earlier and more vigorous; the seated woman, *C.V.A. Lecce*, fasc. II, IV Dr, pl. 12, 4, is not unlike.

13. *Lucanian squat lekythos* (pl. 6*c*).

School of Art, Aa 28. Formerly Palgrave, formerly Pourtales 356.

Neck : curls.

Tongues above main picture. Elaborate palmette complex under handles.

Main scene : boy with cloak over left arm and hand, pursuing woman. Woman wears polos and carries wreath in her left hand and bird in her right hand; she runs towards wool basket.

Early fourth century, Lucanian. Probably later than Munich 3270 (Jacobsthal, *Ornamente*, pl. 110*b*) and near the nuptial lebes, *C.V.A. Bologna*, fasc. III, IV Gr, pl. 3, 6—7.

14. *Apulian œnochœ* (pl. 5*c*).

School of Art, Aa 38. Formerly Palgrave, from Uzielli collection. Square indentation on lip.

Neck : black and white rays, black egg pattern, white dots.

Under handle, elaborate palmette pattern with white dots in all angles. Mæander and St. Andrew's cross under main picture.

Eros, with white and gold wings, hair bound in snood and gold tiara, gold bracelets and leg ornaments, holding a fan in his left hand and in his right, a formal flower, approaches a

seated woman; her face is three-quartered, she holds an iynx in her left hand and a phiale in her right hand. A youth stands on the right with a himation wrapped round his left arm.

Late fourth century, " A.P." (See *J.H.S.* lxiii, 91).

For shape cf. *C.V.A.*, *Compiegne*, pl. 22, 5, 6; *Lecce*, fasc. II, pl. 47, 2.

For stylisation of cloak over left arm of youth cf. *C.V.A.*, *Bologna*, fasc. iii, IV Dr, 12, 2 (probably later), *Cracow, University*, pl. 13, 6 (contemporary).

For general style cf. Würzburg 855.

A Record of Daylight Measurement at Didsbury, 1936—1945.

By B. FARROW

(*British Cotton Industry Research Association*).

SUMMARY.

A photographic method has been used for the continuous recording of the daylight energy, including both sunlight and skylight, falling on a specified surface. The results of measurements in three spectral regions over a period of four months are considered, also of measurements in the region of $\lambda 460$ mμ covering a period of ten years. The latter figures are compared with sunshine duration figures for the locality, and variations in annual totals are discussed in the light of data available from other sources.

INTRODUCTORY.

The records to be described were made in the laboratories of the British Cotton Industry Research Association at Didsbury, Manchester, in connection with investigations on the action of light on textile materials. In this work samples are exposed to daylight, for periods ranging from a few days to many months, and it was desired to have some measurement of the radiant energy falling on the samples.

The method used has been fully described elsewhere.[1] A recording camera gives a continuous trace of log. intensity against time which is subsequently integrated by a photometric device to give an energy figure. The recording camera consists of a light-tight box carrying an opal glass window (the receiving surface) at one end and a clockwork-driven drum at the other. Close behind the window is a narrow slit, parallel to the axis of the drum, covered by an optical wedge with its density gradient along the slit. Lenses suitably placed in a partition across the box form three images of the slit on the drum, which carries three strips of photographic film. This triple arrangement with suitable filters over the lenses allows records to be obtained in three spectral regions. The drum rotates at the rate of one revolution a week and thus each strip of film yields a trace for seven days. The developed record shows the separate days represented by a dense deposit along a base line corresponding

to the traverse of the image of the clear end of the slit, with a fairly sharp outline at a height above the base line depending on the temporal variation of intensity. This contour is precisely defined by an isopaque and as the wedge has constant density increment per unit of length the intensity ordinates on the records are on a logarithmic scale. A calibrating trace, arranged to fall in one of the clear regions of the record corresponding to night time, is imposed on each film by an exposure to a standardized metal filament lamp. Reduction of the logarithmic intensity scale to linearity and intensity-time integration is carried out simultaneously as follows. A contrast print on film is made of the record from the camera : the record thus appears as a number of clear areas (one for each day) on an opaque ground. Each area is placed in turn in a uniform beam of light and covered with an optical wedge of gradient corresponding to the logarithmic intensity ordinate of the record and increasing in density towards its base (*i.e.*, reversed in direction to the taking wedge). The intensity of the light beam thus transmitted is measured photo-electrically, and similarly that transmitted by the standardizing trace. As has been shown, the required daily integral of daylight energy, designated E, can be readily calculated from such measurements. It is expressed as microwatt hours per sq. cm [2] of receiving surface for a wavelength band of 1 mμ width at the wavelength of maximum transmission of the filters concerned.

The recording instrument was set up with its receiving surface at 45° to the vertical close behind a large vertical plate glass window facing 16° east of south and having a practically unobstructed horizon. Didsbury is situated six miles south of Manchester, the immediate surroundings being partly residential and partly open country. Atmospheric conditions are affected in some measure by proximity to industrial S.E. Lancashire and neighbouring towns. Although the sample of daylight thus recorded from, roughly, the south half of the sky is, from the meteorological point of view, an arbitrary one, it is felt that some account of the results obtained is worth putting on record as they cover a fairly long period and although numerous measurements of one aspect and another of daylight have been reported there is rather surprisingly little in the published literature relating to continuous recording of daylight intensity.

Observations at three wavelengths.

Records in three spectral regions were taken for only a comparatively short period when the instrument was first put into use. The selected wavelength bands were around 360, 460 and 560 mμ. Results were obtained for 60 days during July, August, September and October, 1934. The energy values at any one wavelength naturally covered a wide range, those for 460 mμ being always higher than for 360 mμ and generally higher than for 560 mμ. At 460 mμ they ranged from negligibly small values to 225 units. As would be expected the daily values at the three wavelengths ran fairly parallel: the scatter is indicated by taking ratios of daily energy values :—

	460/360	460/560
Mean value of ratios	4·2	1·5
Maximum value of ratios	7·1	4·9
Minimum value of ratios	1·9	0·5
Standard Deviation of ratios	1·2	0·9

Although the quality differences in daylight thus manifested are considerable, even when integration is made over daily periods, it was judged unnecessary, for the purpose in mind, to continue recording at three wavelengths as, in general, interest was in longer periods, over which differences would be further smoothed out.

OBSERVATIONS OVER THE PERIOD OF TEN YEARS, 1936–1945

Records were taken at 460 mμ, and observations covering the period, with only a few short breaks, are available. The full list of daily values, being of only local interest, is not given The results are summarised in Table I as monthly and yearly totals, with the maximum daily value in each month noted. The totals include values for the few lost days inserted by reference to local sunshine figures (see later). The monthly totals show an expected seasonal variation, also variation from year to year, for any one month. Summed over yearly periods the figures still show quite substantial fluctuation : this is brought out in Table II in annual figures expressed as a percentage of the mean for the ten years :—

TABLE I.

Monthly and Annual Totals of E and Sun Hours, and their Ratio. Also Monthly maximum of Daily Values of E.

(E in microwatt hours/cm^2/mμ at λ 460 mμ.)

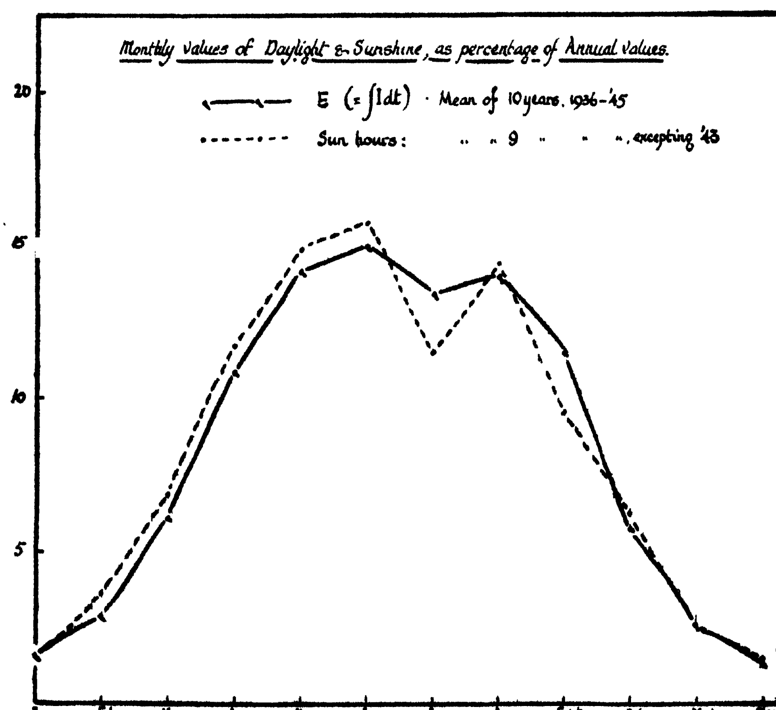
	E		Sunshine (hours)	E/S	E		Sunshine (hours)	E/S	E		Sunshine (hours)	E/S	E		Sunshine (hours)	E/S	E		Sunshine (hours)	E/S
	Total	Maximum daily value			Total	Maximum daily value			Total	Maximum daily value			Total	Maximum daily value			Total	Maximum daily value		
	1936				1937				1938				1939				1940			
Jan.	392	91	14	28	257	23	14	18	685	77	24	29	791	75	18	44	452	32	8	56
Feb.	1193	160	58	21	517	45	28	18	1289	175	41	31	1218	127	32	38	721	96	18	40
March	1393	178	53	26	1152	101	54	21	3215	272	89	36	1981	195	48	41	2021	266	72	28
April	2779	256	117	24	1945	137	83	23	3514	293	111	32	4653	342	140	33	2753	193	70	39
May	3360	274	**158**	21	5570	430	138	40	**5247**	**398**	**151**	35	4539	350	162	28	4529	232	144	31
June	**4006**	254	121	33	5906	449	101	58	4844	328	127	38	**5245**	**876**	**200**	26	**5150**	268	**260**	20
July	2954	203	88	34	5653	784	91	62	3438	251	98	35	3225	217	86	38	4420	259	136	33
Aug.	3655	**314**	133	27	7243	568	**172**	42	3940	320	134	29	3356	226	140	24	4024	**340**	135	30
Sept.	2292	149	78	29	**7286**	**840**	105	69	2800	318	79	37	2253	230	78	29	3549	276	123	29
Oct.	1741	220	65	27	2376	249	48	49	3005	306	68	44	1834	200	64	29	2086	228	64	33
Nov.	458	61	21	22	984	112	27	36	1940	183	49	40	665	56	16	42	850	79	33	26
Dec.	281	29	22	13	301	36	9	34	970	88	20	49	206	25	7	29	385	38	12	32
Yearly total..	24504		928	26	39190		870	45	34977		991	35	29966		991	30	30940		1075	29

	E		Sunshine (hours)	E/S	E		Sunshine (hours)	E/S	E		Sunshine (hours)	E/S	E		Sunshine (hours)	E/S	E		Sunshine (hours)	E/S
	Total	Maximum daily value			Total	Maximum daily value			Total	Maximum daily value			Total	Maximum daily value			Total	Maximum daily value		
	1941				1942				1943				1944				1945			
Jan.	341	29	12	28	295	36	18	16	798	103	13	61	523	50	12	44	486	60	19	25
Feb.	820	108	35	23	619	58	41	15	1410	112	39	36	752	115	29	26	1363	107	43	32
March	2637	**254**	108	24	1494	128	47	32	2032	174	85	24	1791	152	64	28	2937	260	94	31
April	2156	186	85	25	3175	399	**200**	26	3976	296	130	31	4768	299	104	46	4850	335	155	31
May	2911	163	141	21	5509	306	191	29	**6090**	347	198	31	5019	348	136	37	4474	373	136	33
June	**3668**	228	191	19	5509	437	192	29	5538	355	150	37	4578	**437**	95	48	5864	346	155	38
July	3492	236	**196**	18	5538	369	140	40	5821	361	187	31	4493	404	77	58	**5985**	**439**	142	42
Aug.	3252	216	156	21	4869	345	92	53	4737	**421**			**6236**	342	**180**	37	5889	375	**182**	32
Sept.	2079	146	93	22	**5759**	**450**	125	46	4529	332			3863	386	89	43	4096	340	96	43
Oct.	1758	148	89	20	2093	176	52	40	2934	234			2252	263	52	43	2549	241	67	38
Nov.	686	76	26	26	427	72	10	43	888	110			893	144	23	39	888	87	31	29
Dec.	230	38	16	14	637	65	18	35	468	63			554	91	19	29	597	66	18	33
Yearly total.	24044		1147	21	37924		1126	34	39221				35722		869	41	39936		1137	35

In the several columns, maximum values for the year are in bold figures.

TABLE II.

Year.	Daylight energy.	Sunshine hours.
	Annual values, per cent. of mean.	
1936	73	91
1937	116	85·5
1938	104	97
1939	89	97
1940	92	106
1941	71	113
1942	113	111
1943	116	—
1944	106	85·5
1945	119	112



Such variations might, of course, arise from faulty experimentation. Sundry minor changes in procedure, as, for instance, a replacement of the original standard lamp and in the time of exposure used for the standardising trace, have been made from time to time. Proper account has been taken of these and they should not, theoretically, have introduced any discontinuity: this has moreover been checked by experiment. The results are therefore, as far as is known, dependable. The fact that the annual totals, after declining from 1937 to 1941, are high in subsequent years disposes of a fear that was at one time entertained that some untraced factor was introducing a progressive fall in the observed values. The latest year of observations is in fact recorded as the brightest of the ten-year period but the highest daily value was obtained in 1937 (on September 7th) which, with 1943, also had a high annual total.

It is of interest to relate these measurements, recorded as they are in terms of a somewhat special unit and applying as they do to an arbitrary selection of sun and skylight, to more fundamental measurements.

Comparison may be made with the solar constant, 1·94 Cals./cm^2/min. This figure is equivalent of 0·135 watt/cm.^{2} The energy in a 1 mμ band at 460 mμ is, for an average spectrum of sunlight at the earth's surface, about 10^{-3} of the whole. The solar constant thus corresponds to 135 microwatts/cm.^{2}/mμ at λ460 mμ. The average annual total from the measurements here recorded is ca.34,000 microwatt hours/cm.^{2}/mμ, *i.e.*, 90 per day. That is to say, the "average" day corresponds to 90/135 = 2/3 hour of solar radiation as defined in the solar constant.

Some account may be taken of obliquity and atmospheric absorption factors by reference to a computation by Milankovitch[2]. Curves are given showing the theoretical geographical and seasonal distribution of solar radiation at the earth's surface (horizontal surface) for an atmospheric transmission coefficient of 0·7. From these a plot has been made of daily insolation at latitude 52° N (that of Manchester) throughout the year. The area under the curve gives the value of annual insolation—10^5 cals./cm.^{2} This is equivalent to 116,000 microwatt hours/cm.^{2}/mμ at λ460 mμ. The observed value, 34,000 is thus about one-quarter of the theoretical value. This seems not unreasonable.

COMPARISON WITH OTHER OBSERVATIONS.

A. *Local Sunshine Figures.*

Records of sunlight duration are available for a nearby station.* These were taken with the Campbell-Stokes recorder at the Whitworth Park Meteorological Observatory, Manchester (some four miles north of Didsbury). When daily values of E are plotted against hours of sunshine the points are very scattered, but a curve, slightly concave to the sunshine axis, can be drawn through the points. (The relation thus established was used to provide figures for the few days for which observations were missing). It would not be expected that any very close correlation would exist between these entities. The observation that energy values for days of long sunshine tend to be less than proportional to the value for less sunny days is attributed to the fact that direct sunlight of early morning and late afternoon is not recorded in the daylight recorder.

Monthly and annual totals of sunshine are included in Table I,† together with values of the ratio (E/S) of daylight energy to hours of sunshine. This ratio, for monthly figures, covers a fairly wide range and even for yearly periods shows more than a two-fold variation. It will be noticed that the year 1941 with the lowest daylight figure has the highest total of sun hours, and that 1937 with its high daylight value has a low sunshine figure. The annual totals of sun hours, expressed as a percentage of the mean for the nine complete years, are included in Table II.

If, however, the results are presented so as to display the trend of monthly figures through the year a closer agreement is found between the energy and sunshine duration measurements. Individual monthly values, both energy and sunshine, have been expressed as a percentage of the corresponding annual totals. Fig. I shows the mean of such percentages over a period of years, and the substantial agreement between results from the two sources will be noticed. An interesting characteristic of the weather of the locality for the period covered is revealed : June is the brightest month of the year, followed by May and then by August, but a minimum occurs in the curve at July. This is more pronounced in the sunshine duration measurements.

* Figures for the latter part of 1943 are not available, owing to theft of the instrument.

† Figures for the war years had by courtesy from the Whitworth Observer.

The comparison thus reveals a departure from parallelism between the two sets of observations on a long-period basis, but as different entities are involved this is not necessarily surprising. It is hoped in further work to take strictly comparable energy measurements by means of a photoelectric instrument and thus secure an independent check on the photographic method.

B. *Other Continuous Records of Daylight Energy.*

It would seem that not very much has been published in the way of continuous measurement of daylight energy, which is somewhat surprising. Such results as are available are now considered.

A valuable series of observations is reported by Atkins.[3] Continuous measurements were made, using a photoelectric instrument which recorded radiation around $\lambda 410$ mμ, of vertical illumination, at Plymouth. Annual totals for eight years are given, as follows :—

Year.	Vertical illumination integral (in kilolux hours).	As % of the mean.
1930	151,100	126
1931	118,948	99
1932	113,175	94
1933	*ca.* 113,000	94
1934	127,666	106
1935	113,353	94
1936	113,013	94
1937	112,037	93

The outstandingly high figure for 1930 is discussed but considered, from internal and other evidence, to be genuine. Some figures for the vertical radiation integral measured at South Kensington (Meteorological Office) are also quoted. The available annual totals are :

	1930	1931	1936	1937
Vertical radiation integral in gm.cals./cm.^{2}...	165	158	139	139

showing the highest, but not so outstanding, a figure in 1930.

Luckiesh, Taylor and Kerr[4] give the results of a four-year record of U.V. in daylight. They used a photoelectric method, sensitive only to wavelengths less than 335 mμ. Annual totals

of radiation received on a horizontal plane, at a site on the outskirts of Cleveland (U.S.A.) were :—

	1935	1936	1937	1938
E.Viton hours/cm.[2]	2907	2361	2726	2750

(1 E.Viton = 10 microwatts at $\lambda 296.7$ mμ.)

In connection with his pioneering work on smoke abatement Ashworth has obtained records of daylight at several stations in England including towns not far from Manchester. In a brief communication[5] he states that observations extending over 11 years and thus covering a sun-spot cycle indicate maximum intensity of daylight, in both a visible and U.V. region, at sun-spot minimum, falling to a minimum at the spot maximum in 1937 with a subsequent rise as the period of sun-spot minimum approaches. The fluctuations he observes are large : thus "in 1937 U.V. and daylight intensities were, in arbitrary units, 422 and 764, respectively, while last year they rose to 720 and 1817 and are still rising". The method used is presumably that described in a previous paper[6] ; a photographic paper is exposed behind a step wedge, and, for the U.V. record, a filter and the number of steps imprinted is taken as a measure of the intensity. Records were made at Rochdale, Lancs. Some were compared with results obtained elsewhere with a potassium iodide actinometer and curves of annual totals were found to present the same features. Apart from this no check is reported of the constancy of the method, which might be at the mercy of variations in sensitivity of the paper, nor is any calibration indicated. These results, therefore, are not very convincing. There is a possibility, as Atkins points out in the discussion of his results, that variations observed when a narrow band of the spectrum is under investigation may not necessarily correspond to fluctuations in energy received over a wider spectral range. Thus Pettit,[7] in careful observations over 7 years recorded intensities at wavelengths around 310 and 500 mμ ; the ratios, on an arbitrary scale, of the U.V. to green intensities, on the basis of 3-monthly averages were found to range from 0·95 to 1·57 (and showed considerable correspondence with numbers of sun-spot groups). From this point of view it is perhaps unfortunate that observations were not continued, in the present work, at three wavelengths.

Finally, a recent address by Coblentz[8] provides some figures

for "biologically effective" (λ290—320 mμ) ultra-violet solar and sky radiation received on a horizontal plane, at Washington, D.C., and recorded photoelectrically. Monthly totals are graphed for the period February, 1941 to September, 1945. By inserting for the missing four (winter, low intensity) months mean values for the months in question annual totals for the 5 years can be arrived at. These, expressed as a percentage of the mean annual total are : 102, 95·5, 107, 99·5 and 96.

It appears, then, that quite considerable fluctuations may occur in annual totals of daylight. It is a possibility that those found in the present series of observations might be related to a purely local factor, as, for instance, changes in atmospheric pollution, but no very obvious change has occurred in local conditions during the period in question nor does it appear that an explanation along these lines would be supported by the trend of the sunshine figures.

The author thanks the Director and Council of the B.C.I.R.A. for permission to publish this paper. Much of the routine work involved has been done by Miss M. M. Bilsbury and Mr. H. R. Frazer, of this Institute.

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PROCEEDINGS OF THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

Obituaries.

Walter Coventry.

Bo n, 1867. *Died*, 1946.

Walter Coventry was the son of Arthur Coventry (head of the firm of Smith & Coventry) and was a member of the Society of Friends.

After a course of Engineering at Owens College he acted as manager for an industrial concern in Moscow, where he remained from 1892—1899, when unsettled conditions drove many English people out of the country. A period of business on his own account followed, after which he accepted a post with the shipping firm of De Jersey & Co., but here again he was unfortunate since that firm's commitments with Russia were very extensive and the Revolution of 1917 forced them to go out of business. In the spring of 1940 his wide experience and talent for management gained him the post of Assistant Secretary to this Society. Thenceforward in spite of his age (79) and infirmity, he faithfully and conscientiously carried out his duties to the end.

He married Miss Bessie Brown of Moscow, aunt of Wing-Commander Guy Gibson, V.C , of Möhne Valley Dam fame

Robert Henry Clayton

Born, 1872 *Died*, 1946

The death of Robert Henry Clayton on August 12th, 1946, deprived many circles of a member who was highly esteemed for his business ability, his benevolence, and his unsparing devotion to their affairs. Born at Crumpsall, Manchester, in 1872, he was the son of Robert Clayton, the Preston boiler-maker, who died during the infancy of his son , consequently

he was brought up in close association with his grandfather, James Holden, and his uncle, John Holden, who were among the pioneers of industry in Lancashire. At the age of sixteen he was sent to Weimar to complete the early stages of his education, and to his sojourn in that town, which was then a centre of German culture, much of his outlook on life can be traced, particularly his ardent desire for good relationship among nations, the breaking down of national frontiers, and his unswerving support of any scheme for students to spend a year or more abroad. After returning from Germany he entered Owens College, where he studied under Schorlemmer, Dixon, and Perkin, and graduated with honours in chemistry in 1893. On leaving Owens College he joined the staff of the Manchester Oxide Company, Ltd., a company which had been established in the previous year and the development of which was due mainly to his guidance. In 1902 he was appointed a director of this company, also of the parent company of Hardman and Holden, Ltd., and subsequently be became a managing director of the two concerns. He was also a director of Cortonwood Collieries Company, Ltd.

Clayton's association with the University of Manchester was most happy and abiding, and he was very conscious of his indebtedness to the University for the guidance and instruction he had received during his undergraduate days, so much so that he believed that every graduate must be like minded; consequently his thoughts often turned towards a scheme whereby graduates would contribute to the University chest a small percentage of their earned income over a fixed period of years after taking up their first appointments, thus discharging something of the debt they owed and at the same time helping to relieve the University of its financial strain. After his entry into business he maintained a close connection with the Chemistry Department, and a number of the graduates found employment in the firms with which he was associated. He was appointed to the Court of Governors in 1921 and to the University Council in 1925. Unfortunately, after serving for two years, he found that the increasing pressure of business, and particularly his absence from Manchester on business affairs, prevented his attendance at

the meetings, so, acting in accordance with his principles, he resigned in 1927. He was Chairman of Convocation in 1938 and served on the Committee for a long period. In 1939 he was elected as one of the representatives of Convocation on the Court of Governors, a position he held until the time of his death. He took an active interest in the affairs of the College of Technology, especially in the work of the Department of Applied Chemistry, on the Sectional Committee of which he served for many years. He realised that industrial establishments could share with the University and the College of Technology something of the responsibility for the training of scientists and technologists by affording facilities for students to gain first-hand knowledge of industrial life and operations so that they would not be altogether unfamiliar with the conditions in industry on taking up their first appointments; consequently he fostered vacation courses at the Manchester Oxide Company, Ltd., and Hardman and Holden, Ltd. Furthermore, he was always ready to make arrangements for parties of students from the University and the College to visit these establishments. In recognition of his services to the community the University conferred upon him in 1933 the honorary degree of Master of Science, and in the course of the citation at the conferment of this degree it was stated that he had "striven consistently and with marked success to prove the value of science to industry and the value of industry to science."

Clayton was a member of many learned societies. The first with which he became associated was the Society of Chemical Industry, which he joined almost immediately after obtaining his degree of Bachelor of Science. His affection—it was affection—for the Society of Chemical Industry never waned, and it was only a short time before his death that he retired, after many terms of office, from the Committee of the Manchester Section, which he had served so faithfully and well for 52 years and of which he was the Chairman from 1909—1911.

He was particularly interested in the objects of the National Smoke Abatement Society and he served on its executive committee for many years. He gave much time

and thought to the smoke problem, and his efforts to excite the interest of other people, especially the rising generation, in this matter are, perhaps, best exemplified by his institution, at a large girls' school, of prizes for essays on smoke abatement. Knowing that the pollution of the atmosphere and its attendant evils are due chiefly to the burning of bituminous coal in the domestic grate, he thought that the study of the problem by adolescent girls might pave the way to the abatement of the nuisance.

Of the part he played in other professional societies and organisations it is impossible to do justice here; suffice it to say he was a Fellow of the Chemical Society and of the Institute of Fuel, and a member of the Society of Dyers and Colourists, the Institution of Chemical Engineers, the Institution of Gas Engineers, the Coke Oven Managers' Association, and the American Chemical Society.

Clayton was elected a member of the Manchester Literary and Philosophical Society in 1907 What induced him to join is probably beyond recall, but it can be assumed that the Society offered him the very company, discourse, and atmosphere of bygone days in which his heart delighted. Be this as it may, the Society's house became his spiritual home, so much so that he and the house and all that it represented were inseparable. It was inevitable, therefore, that he would be called upon to share in its management, and in November, 1919, he was elected as first Chairman of the Chemical Section, which had been formed as a result of a large influx of chemists into the Society following the dissolution of the first Manchester Chemical Club, of which Clayton had been a founder. The following year (1920) he was elected a Vice-President of the Society, and it is reasonable to assume that in both offices he had applied his knowledge of business and finance to the Society's affairs, so that he was the obvious successor to W. H. Todd as Treasurer of the Society when the office became vacant in 1921. Of Clayton's stewardship of the Society's funds, a stewardship which he retained to the end of his life, much could be said here. Suffice it to say the record is written large in the annals of the Society, and when the full story is told of the part he played in the Society's claims for the loss it

sustained as a result of enemy action in 1940, it will be written larger still. When he was elected President in 1937 he was deeply touched and very mindful of the responsibility he had undertaken ; in fact, he disclosed to the writer his fear lest he should fail to maintain the high traditions of the office to which he had been called. For many years he had given much thought to a scheme for the raising of funds for the provision of scholarships to enable selected graduates to spend a year or more abroad with the object of broadening their outlook before they embarked on careers in industry, and this was the theme of his presidential address, entitled " Training Leaders for Industry ". Clayton was tireless in his search for treasures with which to enrich the Society's collection, and not a few of its valuable possessions were secured as a result of his generosity, while his refurnishing of the French Room to provide a lounge for the lady members further exemplified his benevolence. He was continually evolving ideas for the development of the Society and for extending its sphere of usefulness, and in this connection it is pleasant to recall the active part he took in the arrangements for the " Young People's Meetings ". The destruction of the house and its valuable contents was a great blow to Clayton ; even so, he quickly realised that the Society's work must continue and, despite his years, he dedicated himself to this task. In paying this tribute to his memory I would say, as I have said elsewhere, that his generous nature never permitted him to seek or even to think of any personal reward for the many services he rendered to the community, his maxim through life being—

To set the cause above renown,
To love the game beyond the prize.

W. H. BRINDLEY.

PROCEEDINGS.

1945—1946.

Six ORDINARY MEETINGS were held during the session, at which lectures were delivered as follows :

1945.

Oct. 23rd. "Is Mathematics a Luxury?", by Professor M. H. A. Newman.

Nov. 20th. Short Papers by Members :

(*a*) "Notes on the Gaskell Collection in the Central Library", by Miss M. V. Malcolm-Hayes. (Published *Memoir* 7, Vol. lxxxvii.)

(*b*) "The Relative Merits of Ground Limestone and Quicklime for Agriculture", by Mr. H. F. Taylor. (Published *Memoir* 5, Vol. lxxxvii.)

(*c*) "Birth Rates and Death Rates of Invention", by Mr. W. A. Silvester. (Published *Memoir* 6, Vol. lxxxvii.)

1946.

Jan. 15th. "The Relationship of the Arts", by Principal B. Ifor Evans.

Feb. 5th. Joule Memorial Lecture—"Atomic Energy", by Professor P. M. S. Blackett.

Feb. 21st. "The Climate of Lancashire", by Mr. Gordon Manley. (Published *Memoir* 2, Vol. lxxxvii.)

Mar. 5th. "The Work of the Department of Scientific and Industrial Research in War and Peace", by Sir Edward Appleton. (Published *Memoir* 4, Vol. lxxxvii.)

There were five meetings of the Social Philosophy Section, at which papers were read as follows :

1946.

Feb. 9th. "Greek Civilisation and the Modern World", by Professor T. B. L. Webster. (Published *Memoir* 3, Vol. lxxxvii.)

Mar. 9th. "The Foundations of a Free University", by Miss Dorothy Emmet.

April 6th. "Displaced Persons in Germany", by Mr. Neil Pearson.
"The Situation in Hungary", by Mr. Paul Ignotus.

June 1st. "Natural Law", by the Rev. A. R. Vidler (Published *Memoir* 8, Vol lxxxvii.)

June 22nd. "The Theory of Totalitarianism", by Dr. K. R. Popper.

The ANNUAL GENERAL MEETING was held on May 29th, 1946, in the Council Chamber of the Manchester College of Technology.

ANNUAL REPORT OF THE COUNCIL, MAY, 1946.

Membership.

During the Session 1945-46, 50 new members were elected, bringing the total up to 193, including 13 Life Members. There were 16 resignations during the session

The Council regrets to record the death of one Ordinary Member, Mr. J. T. Allpass.

Meetings.

The Annual General Meeting was held in the Council Chamber of the Manchester College of Technology on Wednesday, July 4th, 1945, when Professor M. Polanyi was re-elected President of the Society.

An Extraordinary General Meeting was held in Professor Polanyi's room, at the University, on December 12th, 1945, at which Mr. J. T. Kendall was elected Hon. Secretary in place of Dr. D. E. Wheeler, who has left the neighbourhood.

On February 5th, 1946, the Joule Memorial Lecture was held in the Great Hall of the Manchester College of Technology and was given by Professor P. M. S. Blackett, F.R.S., Langworthy Professor of Physics, Manchester University, on " Atomic Energy ".

Details of other meetings will be found in the record of Proceedings.

Council Meetings.

Five Council Meetings were held during the session.

On behalf of the Society the Council tenders its thanks to the authorities of the Manchester College of Technology for their kindness in allowing the use of their rooms for lectures and Council Meetings.

Dr. Thomas Percival Lectureship.

This Lectureship was founded in 1945 by a gift of £300 from the Manchester Literary and Philosophical Society to the University in memory of Dr. Thomas Percival, one of the Founders of the Society.

The regulations for the lectureship are as follows :—

(1) A public lecture shall be given as far as possible annually.

(2) The lecture shall be delivered by a member of the staff of the University.

(3) The selection of the lecturer shall be made by a Senate Committee consisting of the members of the Ludwig Mond Committee in conjunction with the President of the Manchester Literary and Philosophical Society.

John Dalton's Grave.

In memory of John Dalton the Society has had his Grave, in Ardwick Cemetery, Manchester, renovated.

Accounts.

An audited financial Statement is attached, together with particulars of assets and liabilities.

Gifts.

The Council expresses the Society's thanks to the donors of the following gifts :—

Memoirs and Proceedings—Vols. 75 to 80 and 82–83 inclusive, from Professor A. D. Ritchie ; Vols. XV–1860, II–1865, III–1868, VII-1870, IV–1871, V–1876, VII–1882, IX–1883, VIII–1884, X–1887, XI–1892, from Miss J. F. Worthington ; Vols. 77–80 and 82–85 inclusive, from W. Anderson.

"The Microscope", by Dr. Carpenter.

"Practical Microscopy", by George E. Davies.

"On mounting microscopic objects", by Thomas Davies.

"Modern Microscopy", by M. I. Cross and Martin J. Cole, from Miss K. M. H. Sidebottom

Gifts of back numbers of the Memoirs and Proceedings will be welcomed. Since the destruction of the library the Society has not been able to make a complete set.

Social Philosophy Section.

At the request of seven members, under the procedure laid down in paragraph 89 of the Society's Articles of Association the Council established the Social Philosophy Section.

The purpose of the Section is to pursue objective and scholarly studies in the sphere of philosophy, economics and sociology.

The Section has held four meetings during the session, details of which will be found in the record of Proceedings.

Air Raid Loss.

The Treasurer's statement re Air Raid Loss will be found with the accounts.

NOTE.—The Treasurer's Accounts of the Session 1945—1946 have been endorsed as follows :

April, 1946, Audited and found correct.

We have seen the Banker's certificate that they hold £375 of 3½ % War Loan Stock :—£300 of 3½ % War Stock : 1 Bond for £50 and a Bond for £25 War Loan 1929-47 Inscribed Stock : and £800 3 % War Stock 1955—1959 : and Bond Book for £250 3 % Defence Bonds : and the certificates of the following Stocks :—£1,225 Great Western Railway Company's 5 % Consolidated Preference Stock, Nos. 31794, 31792 and 31796 ; £7,500 Gas Light and Coke Company Ordinary Stock (Nos. 340891 and 347456) ; £100 East India Railway Company £4 10s. % Annuity Class A Stock (No. 25,656) ; £700 4 % Funding Stock, 1960—1990, Nos. 34,185 and 23/3,457 ; and the deeds of the Natural History Fund, of the Wilde Endowment Fund, those conveying land on which the Society's premises stood, and the Declarations of Trust.

Leases and Conveyances dated as follows :—

September 22nd, 1797.
September 23rd, 1797.
December 25th, 1799.
December 25th, 1799.
December 23rd, 1820.
December 23rd, 1820.

Declarations of Trust :—

June 24th, 1801.
December 23rd, 1820.
January 8th, 1878.

One sealed envelope marked "Papers re 21, Back George Street."

One sealed envelope marked "Board of Trade Deferment Notice."

The certificate for the Dalton and other Medals of the Society.

We have verified the balances of the various accounts with the banker's pass books.

(*Signed*) A. McLEAN RANFT,
G. N. BURKHARDT.

May, 1946.

MANCHESTER LITERARY

R. H. Clayton, Treasurer, in Account with the

GENERAL

	£	s.	d.	£	s.	d.
To Balance at Bank, April 1st, 1945				272	12	7
,, Cash in Treasurer's Hands, April 1st, 1945 .				1	14	3½
,, Members' Subscriptions —						
Full Rate Arrears	3	3	0			
,, ,, 1945–46	165	18	0			
				169	1	0
,, Dividends :—						
Great Western Railway Company's 5 % Consolidated Preference Stock . ..	30	12	6			
East India Railway Company's 4½ % Annuity Class A	3	16	4			
£300 3½ % War Stock	10	10	0			
£75 3½ % War Loan	2	12	6			
£250 Defence Bonds .	7	10	0			
				55	1	4
Sales of Publications				6	14	6½
Donation from R. W. James . .				2	2	0
Bank Interest					12	7
Balance due to Bankers				355	3	10
				£863	2	2

AND PHILOSOPHICAL SOCIETY.

Society, from April 1st, 1945, to March 31st, 1946.

FUND.

	£	s.	d.	£	s.	d.
By Charges on Property :—						
Chief Rent (Net) and Income Tax Sch "D"	12	18	2			
,, Office Expenses	13	0	0			
				25	18	2
Administrative Charges :—						
State Insurance...	4	12	1			
Employers' Liability Insurance		4	6			
Telephone	8	1	6			
Printing and Stationery (incuding cost of Memoirs for 2 years, Vol. 16)	238	1	0			
Lecturers' Expenses and Fees...	32	4	6			
Postage and Carriage	16	2	5			
Miscellaneous Expenses	11	15	0½			
				311	1	0½
Valuer's Opinion on value of books destroyed by enemy action				26	5	0
Legal Expenses arising from damage by enemy action				118	19	0
Endowment of a Thomas Percival Lecture at the Manchester University... ...				300	0	0
Dalton's Grave renovation				57	0	0
Subscriptions to Societies :—						
North-Western Naturalists' Union... ...		14	0			
Ray Society	1	1	0			
Pre-historic Society		15	0			
Palæontographical Society	1	1	0			
Lancashire and Cheshire Fauna Committee	1	1	0			
Malacological Society	1	10	0			
Royal Entomological Society	4	4	0			
				10	6	0
,, Bank Charges and Cheque Book					13	2
,, Cash in Treasurer's Hands				12	19	9½
				£863	2	2

Note.—The item £238 1s. 0d. includes £78 0s. 6d. for 1,000 copies of "Science, the Universities and the Modern Crisis", but there is an estimated £125 0s. 0d. extra cost to be paid on Vol. 86.

WILDE ENDOWMENT FUND, 1945–46.

	£	s.	d.		£	s.	d.
To Balance at Bank, April 1st, 1945 ...	402	14	5	By Salaries, etc.	150	0	0
,, Cash in Treasurer's hands	7	13	4	,, Cash in Treasurer's hands	17	13	4
,, Dividend on £7,500 Gas Light and Coke Company's Ordinary Stock	281	5	0	Cash at Bank	530	17	7
,, Interest on £400 3 % War Stock 1955–59	6	0	0				
,, Bank Interest		18	2				
	£698	10	11		£698	10	11

BUILDING FUND 1945–46.

	£	s	d		£	s.	d
To Balance at Bank, April 1st, 1945 ...	148	14	11	By Balance at Bank, April 1st, 1946	189	2	4
,, Interest on £700 Funding Loan 4 % Stock	28	0	0				
,, Interest on £400 3 % War Stock, 1955–59 .	12	0	0				
,, Bank Interest		7	5				
	£189	2	4		£189	2	4

JOULE MEMORIAL FUND, 1945–46. (Included in the General Account.)

	£	s	d		£	s.	d.
To Dividend on £100 East India Railway Company's 4½ % Annuity Class A Stock	3	16	4	By Cash transferred to General Fund .	14	6	4
,, Interest on £300 3½ % War Stock . .	10	10	0				
	£14	6	4		£14	6	4

NATURAL HISTORY FUND, 1945–46. (Included in the General Account.)

	£	s.	d.		£	s.	d.
To Dividend on £1,225 Great Western Railway Company's 5 % Consolidated Preference Stock	30	12	6	By Cash transferred to General Fund	30	12	6
	£30	12	6		£30	12	6

SIR JOSEPH LARMOR FUND, 1945–46. (Included in the General Account.)

	£	s	d.		£	s	d.
To Interest on £250 Defence Bonds	7	10	0	By Cash Transferred to General Fund	7	10	0
	£7	10	0		£7	10	0

Statement relating to the Society's Property as on March 31st, 1946.

Liabilities.

	£	s.	d.
Amount due to Bank on General Account	355	3	10

Assets.

	£	s.	d.	£	s.	d.
Arrears of Subscriptions, 1943–46	6	6	0			
,, ,, 1944–46	8	8	0			
,, ,, 1945–46	17	17	0			
				32	11	0
Cash Balance :—						
In Bank, Building Fund	189	2	4			
,, ,, Wilde Fund	530	17	7			
,, Treasurer's hands...	30	13	1½			
				750	13	0½
				£783	4	0½

Investments :—

£7,500 Gas Light and Coke Company's Ordinary Stock (W.E.F.) ... ...
£400 3 % War Stock, 1955—1959 (W.E.F.) ... ...
£700 4 % Funding Loan (B.F.) ... ...
£400 3 % War Stock, 1955—1959 (B.F.) ... ...
£100 East India Railway Company's 4½ % Annuity Class A (J.M.F.) ... ...
£300 3½ % War Stock (J.M.F.)... ... ...
£1,225 Great Western Railway Company's 5 % Consolidated Preference Stock (Nat. Hist. F.) ... ...
£75 3½ % War Loan Stock, 1929–47 (G.F.) ... ...
£250 Defence Bonds (Sir J. Larmor F.) ... ...

Income Tax : A claim for repayment of income tax in respect of the year **1944–45** has been forwarded to the Inland Revenue. A claim to repayment for 1945–46 is in the course of preparation.

Loss as a result of enemy action : The claim in connection with the contents of the House and Library which was situate at George Street, Manchester, has been settled at £20,833. This amount has not been paid to the Society and no information is available with regard to the date on which payment will be made. Interest accrued due to the Society in respect of the above figure amounts to £2,745 at 31st March, 1946.

The claim in respect of the Society's property which was situate at 36 George Street, also 21 Back George Street, Manchester, has not been settled.

THE WILDE LECTURES.

1897. (July 2.) "On the Nature of the Röntgen Rays." By Sir G. G. STOKES, Bart., F.R.S.

1898. (Mar. 29.) "On the Physical Basis of Psychical Events." By Sir MICHAEL FOSTER, K.C.B., F.R.S.

1899. (Mar. 28.) "The newly-discovered Elements; and their relation to the Kinetic Theory of Gases." By Professor WILLIAM RAMSAY, F.R.S.

1900. (Feb. 13.) "The Mechanical Principles of Flight." By the Rt. Hon. LORD RAYLEIGH, F.R.S.

1901. (April 22.) "Sur la Flore du Corps Humain." By Dr. ELIE METCHNIKOFF, For. Mem.R.S.

1902. (Feb. 25.) "On the Evolution of the Mental Faculties in relation to some Fundamental Principles of Motion." By Dr. HENRY WILDE, F.R.S.

1903. (May 19.) "The Atomic Theory." By Professor F. W. CLARKE, D.Sc.

1904. (Feb. 23.) "The Evolution of Matter as revealed by the Radio-active Elements." By FREDERICK SODDY, M.A.

1905. (Feb. 28.) "The Early History of Seed-bearing Plants, as recorded in the Carboniferous Flora." Dr. D. H. SCOTT, F.R.S.

1906. (March 20.) "Total Solar Eclipses." By Professor H. H. TURNER, D.Sc., F.R.S.

1907. (Feb. 18.) "The Structure of Metals." By Dr. J. A. EWING, F.R.S., M.Inst.C.E.

1908. (March 3.) "On the Physical Aspect of the Atomic Theory." By Professor J. LARMOR, Sec.R.S.

1909. (Mar. 9.) "On the Influence of Moisture on Chemical Change in Gases." By Dr. H. BRERETON BAKER, F.R.S.

1910. (Mar. 22.) "Recent Contributions to Theories regarding the Internal Structure of the Earth." By Sir THOMAS H. HOLLAND, K.C.I.E., D.Sc., F.R.S.

SPECIAL LECTURES.

1913. (Mar. 4.) "The Plant and the Soil." By A. D. HALL, M.A., F.R.S.

1914. (Mar. 18.) "Crystalline Structure as revealed by X-rays." By Professor W. H. BRAGG, M.A., F.R.S.

1915. (May 4.) "The Place of Science in History." By Professor JULIUS MACLEOD, D.Sc.

DALTON MEMORIAL LECTURES.

1931. (Mar. 17.) "Atoms and Electrons." By Sir JOSEPH J. THOMSON, O.M., D.Sc., F.R.S.

1944. (Oct. 10.) "The Atomic Theory." By Professor A. D. RITCHIE.

JOULE MEMORIAL LECTURES.

1920. (Dec. 14.) "The Work and Discoveries of Joule." By Sir DUGALD CLERK, K.B.E., D.Sc., F.R.S.

1922. (Dec. 5.) "The Rise in Motive Power and the Work of Joule." By Sir CHARLES A. PARSONS, O.M., K.C.B., M.A., D.Sc., F.R.S.

1924. (Mar. 4.) "Thermodynamics in Physiology." By A. V. HILL, O.B.E., M.A., Sc.D., F.R.S.

1928. (Mar. 20.) "Sub-Atomic Energy." By Professor A. S. EDDINGTON, M.A., D.Sc., LL.D., F.R.S.

1930. (Feb. 18.) "Science and Problems of the Times." By A. P. M. FLEMING, C.B.E., M.Sc., M.I.E.E.

1933. (Mar. 14.) "The Psychology of Musical Appreciation." By CHARLES S. MYERS, C.B.E., F.R.S.

1934. (Feb. 27.) "The Expanding Universe as a Thermodynamic System." By Professor E. A. MILNE, M.A., D.Sc., F.R.S.

1936. (Feb. 11.) "The Upper Atmosphere." By Professor E. V. APPLETON, M.A., D.Sc., LL.D., F.R.S.

1938. (Mar. 8.) "The Attainment of Low Temperatures." By Dr. C. G. DARWIN, M.C., M.A., F.R.S.

1940. (Mar. 19.) "New Applications of Physics to Medicine." By Professor JAS. CHADWICK, F.R.S.

1942. (Nov. 10.) "Man and the Weather." By Professor DAVID BRUNT, F.R.S., M.A., Sc.D.

1946. (Feb. 5.) "Atomic Energy." By Professor P. M. S. BLACKETT, F.R.S.

WILDE MEMORIAL LECTURES.

1926. (Mar. 9.) "Brains of Apes and Men." By G. ELLIOT SMITH, M.A., M.D., F.R.S.
1927. (Mar. 22.) "Physiology of Life in the High Andes." By J. BARCROFT, C.B.E., F.R.S.
1929. (Mar. 19.) "The Nature and Origin of Human Speech." By Sir RICHARD PAGET, Bart.
1932. (Mar. 15.) "Man's Place in Nature as shown by Fossils." By Sir ARTHUR SMITH-WOODWARD, LL.D., F.R.S.
1935. (Feb. 12.) "Some Sex Problems in the Fungi." By Professor Dame HELEN GWYNNE VAUGHAN, G.B.E., LL.D., D.Sc., F.L.S.
1937. (Feb. 16.) "Some Problems of the New Stone Age." By HAROLD J. E. PEAKE, M.A., F.S.A.
1939. (Mar. 14.) "Palæolithic Man in the North Midlands." By LESLIE ARMSTRONG, M.C., F.S.I., F.S.A.
1941. (Apr. 29.) "A New Era in Medicinal Treatment." By Sir HENRY H. DALE, President of the Royal Society.
1945. (Mar. 13.) "Some Antibiotics with Special Reference to Penicillin." By Sir HOWARD FLOREY, F.R.S.

Awards of the Dalton Medal.

1898. EDWARD SCHUNCK, Ph.D., F.R.S.
1900. Sir HENRY E. ROSCOE, F.R.S.
1903. Professor OSBORNE REYNOLDS, LL.D., F.R.S.
1919. Professor Sir ERNEST RUTHERFORD, M.A., D.Sc., F.R.S.
1931. Sir JOSEPH J. THOMSON, O.M., D.Sc., F.R.S.
1942. Sir LAWRENCE BRAGG, O.B.E., M.C., F.R.S., D.Sc., M.A.

***A detailed list of the medals, awarded to John Dalton and others, which are the property of the Society, will be found in Memoirs and Proceedings, Vol.* 84, 1939–41, *pp.* xxxi—xxxiii.**

A DETAILED LIST OF ARTICLES SALVAGED

FROM 36, GEORGE STREET, MANCHESTER, AFTER THE DESTRUCTION OF THE BUILDING ON DECEMBER 24TH, 1940, WILL BE FOUND IN *Memoirs and Proceedings*, VOL. 84, 1939–41, *pp*. xxxiv—xxxvii.

LIST OF PRESIDENTS OF THE SOCIETY.

Date of Election.	
1781.	PETER MAINWARING, M D, JAMES MASSEY.
1782–1786.	JAMES MASSEY, THOMAS PERCIVAL, M.D., F.R.S.
1787–1789	JAMES MASSEY
1789–1804	THOMAS PERCIVAL, M D, F R S
1805–1806	Rev. GEORGE WALKER, F R S
1807–1809	THOMAS HENRY, F R S
1809.	*JOHN HULL, M D, F L S
1809–1816	THOMAS HENRY, F R S
1816–1844.	JOHN DALTON, D C L, F R S.
1844–1847	EDWARD HOLME, M D, F L.S.
1848–1850	EATON HODGKINSON, F.R S., F.G S
1851–1854.	JOHN MOORE, F L S
1855–1859	Sir WILLIAM FAIRBAIRN, Bart, LL D, F R.S.
1860–1861	JAMES PRESCOTT JOULE, D C L, F R S
1862–1863	EDWARD WILLIAM BINNEY, F R S, F G S.
1864–1865	ROBERT ANGUS SMITH, Ph D, F R S
1866–1867	EDWARD SCHUNCK, Ph D, F.R S
1868–1869	JAMES PRESCOTT JOULE, D C L, F R S
1870–1871	EDWARD WILLIAM BINNEY, F R S, F G S.
1872–1873	JAMES PRESCOTT JOULE, D C L, F R S
1874–1875.	EDWARD SCHUNCK, Ph D, F.R S
1876–1877	EDWARD WILLIAM BINNEY, F R S, F G.S.
1878–1879.	JAMES PRESCOTT JOULE, D C L, F R S
1880–1881.	EDWARD WILLIAM BINNEY, F.R S, F G.S.
1882–1883.	Sir HENRY ENFIELD ROSCOE, D.C.L., F.R.S.
1884–1885	WILLIAM CRAWFORD WILLIAMSON, LL.D., F.R.S
1886.	ROBERT DUKINFIELD DARBISHIRE, B.A., F.G.S.
1887.	BALFOUR STEWART, LL.D., F R S.
1888–1889.	OSBORNE REYNOLDS, LL D, F R.S.
1890–1891.	EDWARD SCHUNCK, Ph D., F.R.S.

* **Elected April 28th; resigned office May 5th.**

Date of Election.	
1892–1893.	ARTHUR SCHUSTER, Ph.D., F.R.S.
1894–1896.	HENRY WILDE, D.C.L., F.R.S.
1896.	EDWARD SCHUNCK, Ph.D., F.R.S.
1897–1899.	JAMES COSMO MELVILL, M.A., F.L.S.
1899–1901.	HORACE LAMB, M.A., F.R.S.
1901–1903.	CHARLES BAILEY, M.Sc., F.L.S.
1903–1905.	W. BOYD DAWKINS, M.A., D.Sc., F.R.S.
1905–1907.	SIR WILLIAM H. BAILEY, M.I.Mech.E.
1907–1909.	HAROLD BAILY DIXON, M.A., F.R.S.
1909–1911.	FRANCIS JONES, M.Sc., F.R.S.E.
1911–1913.	F. E. WEISS, D.Sc., F.L.S.
1913–1915.	FRANCIS NICHOLSON, F.Z.S.
1915–1917.	SYDNEY J. HICKSON, M.A., D.Sc., F.R.S.
1917–1919.	WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C.
1919.	G. ELLIOT SMITH, M.A., M.D., F.R.S.
1919–1921.	SIR HENRY A. MIERS, M.A., D.Sc., F.R.S.
1921–1923.	T. A. COWARD, M.Sc., F.Z.S., F.E.S.
1923–1925.	H. B. DIXON, C.B.E., M.A., Ph.D., M.Sc., F.R.S., F.C.S.
*1925.	REV. A. L. CORTIE, S.J., D.Sc., F.R.A.S., F.Inst.P.
1925–1927.	H. LEVINSTEIN, D.Sc., M.Sc., F.I.C.
1927–1929.	W. L. BRAGG, O.B.E., M.A., F.R.S.
1929–1931.	C. E. STROMEYER, O.B.E., M.Inst.C.E.
1931–1933.	B. MOUAT JONES, D.S.O., M.A.
1933–1935.	JOHN ALLAN, F.C.S.
1935–1937.	R. W. JAMES, M.A., B.Sc.
1937–1939.	R. H. CLAYTON, M.Sc.
1939–1940.	D. R. HARTREE, M.A., Ph.D., M.Sc., F.R.S.
1940–1944.	H. J. FLEURE, M.A., D.Sc., F.R.S.
1944-1946.	M. POLANYI, Ph.D., M.Sc., M.D., F.R.S.
1946–	T. B. L. WEBSTER, M.A.

LIST OF HONORARY MEMBERS OF THE SOCIETY.

Date of Election.	
Apr. 26th, 1892.	C. LIEBERMANN.
Apr. 17th, 1894.	A. GOUY.
do.	SIDNEY VINES.

* Died May 16th, 1925.

Date of Election.	
Apr. 17th, 1894.	EMIL WARBURG.
Apr. 30th, 1895.	SIR JOSEPH JOHN THOMSON, O.M.
Apr. 24th, 1900.	SIR J. ALFRED EWING.
do.	ANDREW RUSSELL FORSYTH.
do.	ROBERT RIDGEWAY.
May 13th, 1902.	SIR JOSEPH LARMOR.
do.	SIR OLIVER LODGE.
Apr. 28th, 1903.	FRANK WIGGLESWORTH CLARKE.
Apr. 5th, 1910.	WALTHER NERNST.
Nov. 28th, 1922.	NIELS BOHR.
Apr. 13th, 1926.	SAMUEL ALEXANDER, O.M.
do.	ARNOLD SOMMERFELD.
Nov. 16th, 1926	SIDNEY J. HICKSON.
do.	SIR HENRY A. MIERS.
May 13th, 1930.	F. E. WEISS.

LIST OF CORRESPONDING MEMBERS OF THE SOCIETY.

Date of Election.	
Feb. 3rd, 1920.	W. S. MURPHEY.
Nov. 1st, 1921.	MRS. C. W. PALMER.
Nov. 29th, 1923.	H. F. COWARD.
Apr. 1st, 1924.	G. F. FOWLER.
Dec. 16th, 1924.	G. SENN.
Oct. 13th, 1925.	H. G. A. HICKLING.
Nov. 11th, 1941.	MISS E. OWEN.
Dec. 12th, 1944.	H. J. FLEURE.

THE COUNCIL
OF THE
MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.
FOUNDED 1781.

Elected May 29th, 1946.

President.

T. B. L. WEBSTER, M.A.

Vice-Presidents.

H. J. FLEURE, M.A., D.Sc., F.R.S.
D. R. HARTREE, M.A., Ph.D., F.R.S.
M. POLANYI, M.D., Ph.D., M.Sc., F.R.S.
F. C. TOY, D.Sc.

Hon. Secretaries.

R. D. WALLER, M.B.E., M.A.
J. T. KENDALL, M.A.

Hon. Treasurer.

*R. H. CLAYTON, M.Sc.
H. HAYHURST, F.I.C., A.M.I.Chem.E.

Hon. Librarians.

W. H. BRINDLEY, M.C., M.A., M.Sc., Ph.D.
MISS D. EMMET, M.A.

Hon. Curator.

J. R. ASHWORTH, D.Sc.

Chairman, Social Philosophy Section.

M. POLANYI, M.D., Ph.D., M.Sc., F.R.S.

Secretary, Social Philosophy Section.

A. W. JAMES, B.A.

Council.

MISS A. C. ALEXANDER, B.Sc.
LADY BARLOW.
H. B. CHARLTON, M.A.
J. COATMAN, C.I.E., M.A.
E. JAMES, M.A., D.Phil.
J. KENNER, D.Sc., Ph.D., F.R.S.
L. C. KNIGHTS, M.A., Ph.D.
T. W. MANSON, M.A., B.Litt., D.D., F.B.A.
NORMAN SMITH, D.Sc., F.C.S.

*** Deceased August 12th, 1946.**

LIST OF SOCIETIES AND INSTITUTIONS

TO WHICH THE *Memoirs and Proceedings* ARE SENT.

Societies and Institutions present their publications to the Society's Library with the exception of those marked with a dagger (†).

Aberystwyth. †National Library of Wales.

Abo. Akademie Bibliotek.

Adelaide. Royal Society of South Australia. South Australian Museum. Public Library Museum and Art Gallery of South Australia.

Amsterdam. Koninkliijke Akademie van Wetenschappen. Société Mathématique. Bibliothek van het Wickundig en Genootschap.

Auckland. The Auckland Institute and Museum.

Augsburg. Der naturwissenschaftliche Verein für Schwaben.

Baltimore. Johns Hopkins University.

Bamberg. Naturforschende Gesellschaft.

Bangalore (Madras). Indian Institute of Science.

Basle. Naturforschende Gesellschaft. Naturforsch. Gesellsch. Universitats.-Bibliothek. Helvetica Chimica Acta.

Batavia. Natuurkundige Vereeniging in Nederlandsch-Indië. Bataviaasch Genootschap van Kunsten en Wetenschappen.

Bath. Bath and West and South Counties Society.

Belgrade. Académie Royale Serbe.

Belfast. Naturalists' Field Club.

Bergen. Geofysick Institute.

Berkeley. University of California.

Berlin. Deutsche chemische Gesellschaft. Preussische Geologische Landesanstalt. Preussische Akademie der Wissenschaften. Gesellschaft der Naturforschender Freunde.

Besançon. Société d'émulation de Doubs.

Birmingham. Natural History and Philosophical Society.

Bloemfontein. National Museum.

Bologna. Reale Accademia delle Scienze dell'Istituto.

Bombay. Branch of the Royal Asiatic Society of Bengal.

Bonn. Naturhistorischer Verein der preussischen Rheinlande und Westfalens.

Bordeaux. Société des Sciences physiques et naturelles.

Boston. American Academy of Arts and Sciences.

Boulder. University of Colorado.

Bremen. Naturwissenschaftlicher Verein.

Brisbane. Royal Geographical Society of Australasia. Queensland Museum. Royal Society of Queensland.

Bristol. Naturalists' Society.

Brno. Faculty of Science, Masaryk University.

Brooklyn (N.Y.). Institute of Arts and Sciences.

Brussels. Académie Royale de Belgique. Musée Royal d'Histoire Naturelle de Belgique. Société Belge de Géologie Paléontologie et Hydrologie.

Buckhurst Hill. Essex Field Club.

Buenos Aires. Sociedad Cientifica Argentina.

Buffalo. Society of Natural Sciences.

Caen. Académie nationale des Sciences, Arts et Belles-Lettres. †Société Linnéenne de Normandie.

Calcutta. Agricultural Research Institute (Pusa). Geological Survey of India. Indian Association for the Cultivation of Science. Meterological Department of India (Poona). Royal Asiatic Society of Bengal.

Cambridge. Philosophical Society. †University Library.

Cambridge (Mass.) Harvard College. †Massachusetts Institute of Technology Library.

Canberra. National Library.

Cape Town. Royal Society of South Africa. South African Museum.

Cardiff. Naturalists' Society.

Catania. Accademia Gioenia di Scienze naturali.

Chambéry. Académie des Sciences. Belles-Lettres et Arts de Savoie.

Changsa. Geological Survey of China.

Chapel Hill. Elisha Mitchell Scientific Society.

Charlottenburg. Physikalischer-Technischer Reichsanstalt.
Cherbourg. Société nationale des Sciences naturelles.
Chicago. Astrophysical Journal. Field Museum of Natural History. University of Chicago Library.
Cincinnati. Lloyd Library and Museum. †American Association for the Advancement of Science. Society of Natural History.
Clermont-Ferrand. La Société des amis de l'Université de Clermont.
Colorado Springs. Colorado College Coburn Library.
Columbia. University of Missouri.
Columbus. Ohio Journal of Science. Ohio State University.
Copenhagen. Kongeligt Danske Videnskabernes Selskab. Kongeligt Nordisk Oldskrift-Selskab. Naturhistorisk Förening.
Cracow. Société Polonaise Mathématique.
Cullercoats. See Newcastle-upon-Tyne.

Danzig. Naturforschende Gesellschaft. Westpreussischer Botanisch-Zoologischer Verein.
Davenport. Academy of Natural Sciences.

Delft. Technische Hoogeschool.
Dijon. Académie des Sciences, Arts et Belles-Lettres.
Dorpat. Naturforschende Gesellschaft. Universitas Tartuensis.
Douai. Société d'Agriculture, Sciences et Arts du Département du Nord.
Draguignan. Société d'études scientifiques et archéologiques.
Dublin. †National Library of Ireland. Royal Dublin Society. Royal Irish Academy. †Trinity College Library.
Dunkerque. Société Dunkerquoise pour l'encouragement des Sciences.
Durban. †Corporation Museum.

Edinburgh. Botanical Society. Geological Society. Mathematical Society. †National Library of Scotland. Royal Botanic Gardens. Royal Observatory. Royal Physical Society. Royal Society. Royal Scottish Society of Arts. †Scottish Meteorological Society. University Library.

Elberfeld. Naturwissenschaftlicher Verein.
Epinal. Société d'émulation des départements des Vosges.
Erlangen. Physikalisch-medizinische Societät.
Evreux. Société libre d'Agriculture, Sciences, Arts et Belles-Lettres de d'Eure.

Falmouth. Royal Cornwall Polytechnic Society.
Florence (Firenze). Biblioteca Nazionale Centrale.
Frankfurt-am-Main. Physikalischer Verein. Senckenbergische Naturforschende Gesellschaft.
Freiburg i. Br. Naturforschende Gesellschaft.

Geneva. Institut national Génévois. Société de Physique et d'Histoire Naturelle. See also Basle.
Genova. Museo Civico di Storia Naturale.
Giessen. Oberhessische Gesellschaft für Natur-und Heilkunde.
Glasgow. Geological Society. Glasgow and Andersonian Natural History and Microscopical Society. Royal Philosophical Society. †University Library.
Görlitz. Naturforschende Gesellschaft.
Göteborg. Göteborgs Stadtsbibliotek (Högskole).
Göttingen. Gesellschaft der Wissenschaften.
Grahamstown. Albany Museum.
Granville. Denison University.
Graz. Verein des Aertze in Steiermark.
Greenwich. Royal Observatory.

Haarlem. Hollandsche Maatschappig der Wetenschappen. Musée Teyler. Nederlandsche Maatschappig ter bevordering van Nijverheid. Geologisch Bureau van het Nederlandsch Mijngebied.
Halifax, N.S. Nova Scotian Institute of Science.
Halle. Akademie der Naturforscher. Naturforschende Gesellschaft und naturwissenschaftlicher Verein.
Hamburg. Naturwissenschaftlicher Verein. Mathematische Gesellschaft.
Hanley. See Stoke-on-Trent.
Hanover. Naturhistorische Gesellschaft.
Hartford (Conn.). Connecticut State Library (Geological and Natural History Survey).

Heidelberg. Badische Sternwarte. Naturhistorischmedizinischer Verein.

Helsingfors. Finska Vetenskaps Societeten. Societas pro Fauna et Flora Fennica.

Hermannstadt. Siebenbürgischer Verein für Naturwissenschaften.

Hobart. Royal Society of Tasmania.

Hong Kong. Royal Observatory.

Hull. †Scientific and Field Naturalists' Club. †Yorkshire Naturalists' Union.

Indianapolis. Department of Geology and Natural Resources of Indiana.

Iowa City. Iowa State University. Iowa Geological Survey.

Ithaca. Cornell University. Agricultural Experimental Station.

Johannesburg. South African Association for the Advancement of Science.

Kazan. Imperial University. Society of Archæology.

Kiel. Naturwissenschaftlicher Verein für Schleswig-Holstein. Institut für Meereskunde der Universität Kiel.

Kiev. Academy of Sciences of the Ukrainian Soviet Socialistic Republic. The Academy Institute for Physical Chemistry.

Kodaikanal. See Madras.

Königsberg i. Pr. Universitäts-Sternwarte. Physikalisch-ökonomische Gesellschaft.

Kyoto. College of Science and Engineering, Imperial University.

Lausanne. Société Vaudoise des Sciences Naturelles.

Lawrence. Kansas University.

Leeds. Geological Association. Philosophical and Literary Society. Yorkshire Geological Society.

Leeuwarden. Friesch Genootschap, van Geschied-, Oudheid -en Taalkunde.

Leicester. Literary and Philosophical Society.

Leiden. Maatschappig der Nederlandsch Letterkunde. Rijks Geologisch—Mineralogisch Museum. Rijks Herbarium. Société Néerlandaises de Zoologie.

Leipzig. Naturforschende Gesellschaft. Jablonowskische Gesellschaft. Sächsische Gesellschaft der Wissenschaften.

Le Mans. Société d'Agriculture, Sciences et Arts de la Sarthe.

Lemberg. Bibliothek der Sevcenk Gesellschaft.

Leningrad. Academy of Sciences of the Union of Socialist Soviet Republics.

Liége. Société Géologique de Belgique. Société Royale des Sciences.

Lille. Société des Sciences d'Agriculture et des Arts. L'Universitaire.

Lima, Peru. Cuerpo de Inginieros de Minas del Peru.

Lincoln, U.S.A. Nebraska Geological Survey. University of Nebraska.

Lisbon. Observatorio Central Meteorologico. Observacões meteorologicas da Madeira.

Liverpool. Biological Society. Engineering Society. Geological Society. Hartley Botanical Laboratories. Literary and Philosophical Society.

London. British Association. British Museum (Natural History). British Museum (Library of Pure and Applied Science). British Museum Copyright Office. Chemical Society. Faraday Society. Geological Society. Institution of Civil Engineers. Institution of Electrical Engineers. Institution of Mechanical Engineers. Linnean Society. Mathematical Society. Meteorological Office. National Central Library. Patent Office. Physical Society. Quekett Microscopical Society. Royal Society. Royal Astronomical Society. Royal Geographical Society. Royal Horticultural Society. Royal Institute of British Architects. Royal Institution of Great Britain. Royal Meteorological Society. Royal Observatory. Royal Society of Arts. †Subject Index to Periodicals. University Library. Zoological Society.

Lucca. Reale Accademia Lucchese di Scienze, Lettere, ed Arti.

Lund. The University Library.

Luxembourg. Institut Grand Ducal de Luxembourg.

Lwow. See Lemberg.

Lyon. Académie des Sciences. L'Université.

Madison. Wisconsin Academy of Sciences, Arts and Letters, Wisconsin Geological and Natural History Survey.

Madras. Observatory (Kodaikanal). University.

Madrid. Academia de Ciencias. Sociedad Matemática Española.

Manchester. Association of Engineers. †Chetham's Library. †Christie Library. Conchological Society. Geographical Society. Geological Association. Microscopical Society. †Municipal College of Technology. †Central Library. Shirley Institute. Statistical Society. Textile Institute.

Manhattan. Library of Kansas State College of Agriculture and Applied Science.

Manila. Bureau of Science. Ethnological Survey.

Marburg. Gesellschaft zur Beförderung der gesammten Naturwissenschaften.

Marseilles. Faculté des Sciences de l'Université.

Melbourne. Royal Society of Victoria.

Metz. Académie de Metz.

Mexico. Instituto Geológico. Academia Nacional de Ciencias. "Antonio Alzate."

Middleburg. Zeeuwsch Genootschap der Wetenschappen.

Milan. Reale Istituto Lombardo di Scienze e Lettere. Reale Osservatorio di Brera in Milano (Merati, Como.). Società Italiana di Scienze Naturali, e Museo Civico.

Minneapolis. University of Minnesota. †Academy of Natural Sciences.

Missoula. University of Montana.

Modena. Regia Accademia di Scienze, Lettere ed Arti.

Montevideo. Museo de Historia Natural.

Montpellier. Académie des Sciences et Lettres.

Moscow. Société des Naturalistes de Moscou.

Munich. Bayerische Akademie der Wissenschaften.

Nancy. Société des Sciences de Nancy.

Naples. Accademia delle Scienze fisiche e matematiche. Accademia di Archeologia, Lettere e Belle Arti. Società Reale di Scienze.

Neuchâtel. Société neuchâteloise des Sciences naturelles.

Newcastle-upon-Tyne. Dove Marine Laboratories, Cullercoats. †Literary and Philosophical Society. Natural History Society of Northumberland, Durham, and Newcastle-upon-Tyne. University of Durham Philosophical Society.

New Haven (Conn.). Connecticut Academy of Arts and Sciences. Bingham Oceanographic Collection.

New York. Academy of Sciences. American Chemical Society. American Mathematical Society. American Museum of Natural History. Meteorological Observatory (Central Park). The Vanderbilt Marine Museum.

Nîmes. Académie de Nîmes.

Norman. Oklahoma Academy of Science.

Norwich. Norfolk and Norwich Naturalists' Society.

Offenbach. Der Offenbacher Verein für Naturkunde.

Oporto. Academica Polytechnica Porto.

Oslo. Norske Videnskaps Akademie. Norsk Meteorologisk Institut. Observatorium. Bibliothèque de l'Université Royale de Norvège.

Ottawa. Dominion Astrophysical Observatory. Geological Survey of Canada. Royal Society of Canada.

Oxford. †Bodleian Library. Radcliffe Library.

Palermo. Reale Accademia di Scienze, Lettere, e Belle Arti.

Paris. Académie des Sciences. École nationale supérieure des Mines. École polytechnique. Muséum d'Histoire naturelle.

Peiping. Geological Society of China.

Philadelphia. Academy of Natural Sciences. American Philosophical Society. Franklin Institute. †Philadelphia Commercial Museum. Wagner Free Institute of Science.

Pietermaritzburg. †Government Geologist, Surveyor General's Office. Natal Government Museum.

La Plata. Direccion General de Estadistica de la Prov. Buenos Aires. Universidad Nacional, Facultad de Ciencias Fisico-Matematicas.

Plymouth. Plymouth Institution and Devon and Cornwall Natural History Society.
Poona. (See Calcutta.)
Portici. Laboratorio di Zoologia generale e agraria, R. Scuola sup. di Agricoltura.
Prague. Böhmische Gesellschaft der Wissenschaft.
Pretoria. The University.
Puget Sound. See Seattle.
Pusa. See Calcutta.

Rennes. Société Scientifique de Bretagne.
Rheims. Académie nationale.
Riga. Naturforscher Verein.
La Rochelle. Société des Sciences naturelles de la Charente inférieure.
Rochdale. Literary and Scientific Society.
Rochester, N.Y. Academy of Science.
Rock Island. Augustana College Library.
Rome. Institut International d'Agriculture. Reale Accademia dei Lincei. Società Italiana per il progresso delle Scienze. Vatican Observatory (Specola Vaticana).
Rostock. Verein der Freunde der Naturgeschichte in Mecklenburg.
Rouen. Académie des Sciences.

Sacramento. See Berkeley.
St. Louis. Missouri Botanical Garden. †Academy of Science The Washington University.
St. Paul. See Minneapolis.
Salford. †Royal Museum and Library.
San Diego. Society of Natural History.
San Francisco. California Academy of Sciences.
Santiago. Deutscher wissenschaftlicher Verein.
Sassari. Regia Università Istituto Fisiologico.
Seattle. University of Washington. Oceanographical Laboratories. Puget Sound Marine Biological Station.
Sendai. Tohoku Imperial University.
Sheffield. Midland Institute of Mining, Civil and Mechanical Engineers. Safety in Mines Research Board Laboratories.
Shrewsbury. Caradoc and Severn Valley Field Club.

Simla. See Calcutta.

Southport. Fernley Observatory.

Stockholm. Entomologiska Föreningen. Kongeliga Svenska Vetenskaps-Akademi. Royal Library. Sveriges Geologiska Undersökning. Stockholms Högkolas Bibliotek.

Stoke-upon-Trent. North Staffordshire Field Club.

Stratford. The Essex Field Club.

Swansea. Scientific and Field Naturalists' Society.

Sydney. Australian Museum. Linnean Society of New South Wales. Royal Society of New South Wales.

Tashkent. L'Université de l'Asie Centrale.

Taihoku. Imperial University.

Tartu. See Dorpat.

Teddington. National Physical Laboratory.

Tiflis. Geophysikalisches Observatorium Georgiens.

Tokyo. Faculty of Science, Imperial University of Tokyo. Imperial Academy. Institute of Electrical Engineers of Japan. Institute of Physical and Chemical Research. Physico-Mathematical Society of Japan. National Research Council of Japan.

Toronto. University Library.

Toulouse. Académie des Sciences, Inscriptions, et Belles-Lettres.

Trondhjem. Kongelige Norske Videnskabers Selskab Museet.

Troyes. Société Académique d'Agriculture de l'Aube.

Tufts, Massachusetts. Tufts College.

Uccle. L'Observatoire royale et l'Institut royal Météorologique de Belgique.

Ukraine. (See Kiev.)

Upsala. Kongeliga Universitet. Kongeliga Vetenskaps-Societeten.

Urbana. Illinois State Geological Survey. Illinois State Laboratory of Natural History. University of Illinois.

Utrecht. Koninklijk Nederlandsch Meteorologisch Instituut. Provincial Utrechtsch Genootschap van Kunsten en Wetenschappen.

Venice. Reale Istituto Veneto di Scienze, Lettere, ed Arti.
Victoria, B.C. Dominion Astrophysical Observatory.
Vienna. Akademie der Wissenschaften. Universitäts-Sternwarte. Naturhistorisches Museum. Zoologisch-Botanische Gesellschaft. Oesterreichische Gesellschaft für Meteorologie.

Washington University. See St. Louis, Mo.
Washington, University of. See Seattle.
Washington, D.C. Bureau of Standards, Dept. of Commerce and Labor. Carnegie Institute. Smithsonian Institution, Bureau of Ethnology. Smithsonian Institution, United States National Museum. U.S. Coast and Geodetic Survey. U.S. Department of Agriculture. U.S. Geological Survey. U.S. Naval Observatory. †U.S. Patent Office.
Watford. Hertfordshire Natural History Society and Field Club.
Wellington, N.Z. Royal Society of New Zealand.
Wiesbaden. Nassauischer Verein für Naturkunde.
Wurzburg. Physikalisch-medizinische Gesellschaft.

York. Yorkshire Philosophical Society.

Zürich. Naturforschende Gesellschaft. Schweizerischer Meteorologische Central-Anstalt.

LIST OF ORDINARY MEMBERS OF THE SOCIETY, MAY, 1943.

(The death of the Assistant Secretary, and the long delay in finding a successor, have made it impossible to revise this list in time. It will be brought up to date in the next issue.)

Year of Election.

1928. Eric Ahlquist, The Croft, Ladybrook Road, Bramhall Park, Cheadle Hulme, Cheshire.
1920. Miss A. C. Alexander, B.Sc., c/o Messrs. Tootal Broadhurst Lee Co. Ltd., 56, Oxford Street, Manchester, 1.
1920. John Allan, F.C.S., 18, Moorfield Road, West Didsbury, Manchester, 20.
1922. J. T. Allpass, 34, Roxton Road, Heaton Chapel, Stockport.
1942. Dr. Alexander Altmann, 38, Waterpark Road, Salford, 7.
1921. W. Anderson, B.Sc., The College of Technology, Manchester, 1.
1928. G. E. Archer, M.B., Ch.B., D.L.O., F.R.C.S.(Ed.), West Thorpe, Park Road, Bowdon, Cheshire.
1943. A. Leslie Armstrong, M.C., M.Sc., F.S.I., F.S.A., 20, Princess Street, Manchester.
1926. J. R. Ashworth, D.Sc., 55, King Street South, Rochdale.
1920. F. W. Bailey, Haven House, Broadbottom, Cheshire.
1940. Mrs. E. A. Bardsley, Alexandra House, 7, Queens Road, Oldham.
1938. F. H. Bentley, M.B., F.R.C.S., 1, Lorne Street, Upper Brook Street, Manchester, 13.
1919. W. H. Bentley, D.Sc., F.C.S., Logan Rock, 188, Birkenhead Road, Meols, Wirral, Cheshire.
1937. Professor P. M. S. Blackett, M.A., F.R.S., St. Clare, Park Avenue, Ruislip, Middlesex.
1920. R. W. Blakeley (Life Member), 299, Great Clowes Street, Salford, 7.
1914. Frank Bowman, M.A., M.Sc.Tech., 12, Clifton Avenue, Fallowfield, Manchester, 14.
1914. Major A. W. Boyd, M.C., M.A., F.R.E.S., Frandley House, Near Northwich.

Year of Election.

1927. J. Crighton Bramwell, M.A., M.D., F.R.C.P., 15, Lorne Street, Manchester, 13.
1936. W. H. Brindley, M.C., M.A., M.Sc., Ph.D., 11, Pikes Lane, Glossop, Derbyshire.
1938. F. J. Brown, M.Sc., The University, Manchester, 13.
1934. Ernest Brunner, Ph.D., Oak Tree Cottage, Castle Hill, Prestbury.
1929. H. E. Buckley, D.Sc., Bradda, Hazelhurst Road, Worsley, Lancs.
1936. *Professor W. Ll. Bullock, M.A., Ph.D., Arborfield, Langham Road, Bowdon, Cheshire.
1925. G. N. Burkhardt, M.Sc., Ph.D., F.I.C., The University, Manchester, 13.
1941. Miss A. Burton, Slethos House, 68, Sackville Street, Manchester, 1.
1920. Miss Marion Chadwick, M.Sc.Tech., 1, Didsbury Road, Stockport.
1899. D. L. Chapman, M.A., F.R.S., Jesus College, Oxford.
1943. Professor H. B. Charlton, M.A., The University, Manchester, 13.
1943. Socrates Emanuel Chiotides, 29, Minshull Street, Manchester, 1.
1929. J. D. Chorlton, M.Sc., 62, Palatine Road, Withington, Manchester, 20.
1939. G. F. Clayton, 1, Parkfield Road, Didsbury, Manchester.
1929. J. H. Clayton, Lymm Hall, Lymm, Cheshire.
1920. R. H. Clayton, M.Sc., 1, Parkfield Road, Didsbury, Manchester, 20.
1922. Miss Gladys Clegg, M.Sc., 28, Winwood Road, East Didsbury, Manchester, 20.
1941. John Coatman, C.I.E., M.A., c/o The Firs, Fallowfield, Manchester, 14.
1928. A. F. Core, M.Sc., The University, Manchester, 13.
1928. C. G. Core, M.Sc., The University, Manchester, 13.
1938. T. G. Cowling, M.A., D.Phil., The University, Manchester, 13.

Year of Election.

1934. Miss R. E. S. Cox, Kingsmoor School, Glossop, Derbyshire.

1916. Mrs. M. B. Craven, M.Sc.Tech. (Life Member), College of Technology, Manchester, 1.

1944. H. S. Critchley, Three Gates, Higher Disley, Cheshire.

1919. Miss Mary Cunningham, D.Sc., 27, Clarence Terrace, Bollington, Nr. Macclesfield.

1923. George W. Cussons, The Technical Works, Lower Broughton, Manchester, 7.

1929. J. A. Darbyshire, M.Sc., Melandra, Kershaw Street, Failsworth, Manchester.

1944. William Dick, M.A., K.C., 105, Station Road, Cheadle Hulme, Cheshire.

1942. Miss Lois Dickinson, 31, Charnock Avenue, Wollaton Park, Nottingham.

1918. Miss Annie Dixon, M.Sc., F.R.M.S., (Life Member), Kauguri, Batchwood Drive, St. Albans.

1930. Professor J. M. F. Drummond, M.A., F.R.S.E., 87, Wellington Road, Fallowfield, Manchester, 14.

1941. Morris Feinmann, 18, Roston Road, Salford, 7.

1942. W. R. Fielding, M.A., M.Sc., M.Ed., Manor House, Manor Road, Fleetwood.

1924. A. P. M. Fleming, C.B.E., M.Sc.Tech., M.I.M.E., Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.

1932. Professor H. J. Fleure, M.A., D.Sc., F.R.S., Bowdoin College, Brunswick, Maine, U.S.A.

1940. R. P. Foulds, M.Sc., F.I.C., F.T.I., c/o Messrs. Tootal Broadhurst Lee Co. Ltd., 56, Oxford Street, Manchester, 1.

1922. P. Gaunt, A.I.C., Pentire, Park Lane, Hale, Cheshire.

1922. A. Gill, B.Sc., A.I.C., Hardwick, 30, Woodhill Drive, Prestwich, Nr. Manchester.

1926. W. Howard Goulty (Life Member), 6, Brown Street, Manchester, 1.

Year of Election.

1944. Julius Grant, M.Sc., Ph.D. (Lond.), F.R.I.C., Standleigh, Ringley Road, Whitefield, Manchester.

1929. Professor D. R. Hartree, M.A., Ph.D., F.R.S. (Life Member), 1, Didsbury Park, Didsbury, Manchester, 20.

1924. H. Hayhurst, F.I.C., A.M.I.Chem.E., Fouray, Parkfield Road, Didsbury, Manchester, 20.

1924. Mrs. H. Hayhurst, M.Sc., Fouray, Parkfield Road, Didsbury, Manchester, 20.

1921. D. C. Henry, M.A., The University, Manchester, 13.

1919. D. M. Henshaw, c/o Messrs. W. C. Holmes & Co. Ltd., Engineers, Huddersfield.

1928. J. B. M. Herbert, M.Sc., The University, Manchester, 13.

1942. Professor D. H. Hey, King's College, Strand, London, W.C.2.

1943. Allan Howard Hilton, 135, Great Clowes Street, Manchester, 7.

1944. Samuel Hird, O.B.E., M.Sc., 12, Oakland Avenue, Stockport.

1936. K. G. Holden, B.A., Downshot, Alderley Edge, Cheshire.

1936. N. N. Holden, Braeside, Altrincham, Cheshire.

1943. Ernest Hollings, Dunleath, 17, Alexandra Road, Sale, Cheshire.

1944. Rev. R. V. Holt, Unitarian College, Victoria Park, Manchester, 14.

1920. T. Horner, M.Sc.Tech., A.I.C., (Life Member), c/o The District Bank, Dalaunay Road, Crumpsall, Manchester, 8.

1926. O. R. Howell, B.Sc., Ph.D., Spey Lodge, 29, Palatine Road, Withington, Manchester, 20.

1909. Frederick Howles, D.Sc., Glenluce, Waterpark Road, Broughton Park, Manchester, 7.

1944. Frank Howlett, M.Sc., Ph.D., 49, Parrswood Avenue, Didsbury, Manchester, 20.

1919. Henry Humphreys, 101, Frederick Street, Oldham.

Year of Election.

1923. J. Wilfrid Jackson, D.Sc., F.G.S., The Manchester Museum, The University, Manchester, 13.

1943. Professor Willis Jackson, Penlee, Knutsford Road, Wilmslow.

1923. R. W. James, B.Sc., The University, Cape Town, South Africa.

1943. Professor Geoffrey Jefferson, High Bank, Stenner Lane, Didsbury, Manchester, 20.

1943. Mrs. Jefferson, High Bank, Stenner Lane, Didsbury, Manchester, 20.

1942. C. W. Jones, M.A., Ellesmere House, Ellesmere Park, Eccles, Manchester.

1924. Francis Jones, F.R.I.B.A., 178, Oxford Road, Manchester, 12.

1923. P. Guthlac Jones, Malista, Limefield Road, Kersal, Manchester, 7.

1928. Professor J. Kenner, D.Sc., Ph.D., F.R.S., The College of Technology, Manchester, 1.

1940. C. M. Keyworth, M.Sc. (Leeds), F.I.C., A.M.I.Chem.E., Churnet Works, Leek, Staffs.

1940. P. Krug, Dr. Nat. Science (Prague), Manchester Oxide Co. Ltd., Canal Street, Collyhurst, Manchester, 10.

1931. H. S. Land, 24, Hillington Road, Ashton-on-Mersey, Cheshire.

1909. Professor W. H. Lang, M.B., C.M., D.Sc., M.Sc., F.R.S., 2, Heaton Road, Withington, Manchester, 20.

1919. J. E. Lea, B.Sc., M.I.Mech.E., c/o Lea Recorder Co. Ltd., Recorder House, Cornbrook Park Road, Manchester, 15.

1917. Sir Kenneth Lee, LL.D., Messrs. Tootal Broadhurst Lee Co., Ltd., 56, Oxford Street, Manchester, 1.

1940. H. R. Leech, The Lindens, Balmoral Road, Grappenhall, near Warrington.

1931. Miss C. M. Legge, M.A., A.R.C.A., 115, Banbury Road, Oxford.

1943. Miss Myee Dorothy Leigh, M.A., Lyncroft, Higher Ainsworth Road, Radcliffe, Manchester.

Year of Election.

1943. Miss Margaret Lever, Lyncroft, Higher Ainsworth Road, Radcliffe, Manchester.

1944. Miss E. M. Lind, B.Sc., Ph.D., Ashburne Hall, Fallowfield, Manchester, 14.

1941. W. A. Locan, The Firs, Talbot Road, Glossop.

1938. A. C. B. Lovell, B.Sc., Ph.D., 29, Parkwood Road, Northenden.

1928. H. Lowery, D.Sc., Ph.D., M.Ed., F.Inst.P., F.C.P., Principal, South-West Essex Technical College, Forest Road, London, E.17.

1936. G. W. Mack, B.A., 30, Lonsdale Road, Manor Road, Levenshulme, Manchester, 19.

1941. Rev. H. McLachlan, M.A., D.D., 11, Sydenham Avenue, Liverpool, 17.

1943. Miss Marion V. Malcolm-Hayes, Mayfield, The Hough, Wilmslow.

1930. Miss I. Manton, B.A., Sc.D., Ph.D., The University, Manchester, 13.

1931. E. N. Marchant, Whetherstones, Wilbraham Road, Chorlton-cum-Hardy, Manchester, 21.

1941. A. R. Martin, 20, Styal Road, Wilmslow, Cheshire.

1929. H. G. Mather, Sunnymead, Hamilton Road, Whitefield.

1944. J. M. Meek, 79, Temple Road, Sale, Cheshire.

1939. Mrs. A. D. Melland, 17, Ladybarn Road, Fallowfield, Manchester, 14.

1939. C. H. Melland, M.D., 17, Ladybarn Road, Fallowfield, Manchester, 14.

1927. W. Melland, M.A., J.P., 1B, Cooper Street, Manchester, 2.

1944. Rev. F. H. A. Micklewright, M.A., 25, Albert Road, Whalley Range, Manchester.

1936. Professor John Morley, Ch.M., F.R.C.S., The Elms, Wilmslow Road, Didsbury, Manchester, 20.

1912. J. E. Myers, O.B.E., D.Sc., College of Technology, Manchester, 1.

1942. *Sir Christopher T. Needham, Fair Oak, Palatine Road, West Didsbury, Manchester, 20.

1927. J. M. Nuttall, D.Sc., The University, Manchester, 13.

Year of Election.

1936. T. H. Oliver, M.D., Northern Assurance Buildings, Albert Square, Manchester, 2.

1942. David Pearson, B.A., 22, Dryden Avenue, Cheadle, Cheshire.

1934. Professor M. Polanyi, M.D., Ph.D., M.Sc., F.R.S., 30, Sandileigh Avenue, Withington, Manchester, 20.

1931. Professor W. J. Pugh, O.B.E., B.A., D.Sc., F.G.S., Rathen House, Spath Road, Didsbury, Manchester, 20.

1931. A. McLean Ranft, 1, Framingham Road, Brooklands, Cheshire.

1923. Professor H. S. Raper, C.B.E., D.Sc., M.B., Ch.B., M.Sc., F.R.S., The University, Manchester, 13.

1929. Dr. W. J. Sutherland Reid, Cringle, Cheadle, Cheshire.

1920. Professor A. D. Ritchie, M.A., (Life Member), The University, Manchester, 13.

1909. Miss Rona Robinson, M.Sc., F.I.C., (Life Member), Mosley Villa, Mitford Road, Fallowfield, Manchester.

1943. Gregory G. Sarris, c/o Messrs. R. Street & Co., 15, Cross Street, Manchester.

1944. R. U. Sayce, M.A., M.Sc., The University, Manchester, 13.

1919. F. Scholefield, M.Sc., The College of Technology. Manchester, 1.

1931. J. Shirley, M.Sc., Department of Geology, The University, Sheffield, 10.

1920. W. A. Silvester, M.Sc. (Life Member), 4, Claremont Road, Cheadle Hulme, Cheshire.

1941. A. P. Simon, Lyndale, West Didsbury, Manchester, 20.

1915. Sir Ernest D. Simon, M.A., M.Inst.C.E., Broomcroft, Ford Lane, Didsbury, Manchester, 20.

1906. Norman Smith, D.Sc., F.C.S., 22, Broadway, Withington, Manchester, 20.

1926. W. M. Speight, M.Sc., The Grammar School, Manchester, 13.

Year of Election.

1911. Miss Laura E. Start, M.Ed., Holmwood, Mayfield Road, Kersal, Manchester, 7.

1921. Harold Stevenson, F.I.C., Slievemore, 9, Westwood Road, Heald Green, Cheshire.

1936. Sir John S. B. Stopford, M.D., Sc.D., F.R.S., The University, Manchester, 13.

1936. J. F. Straatman, Ir. (Delft), A.T.I., 208, Heywood Road, Prestwich, Manchester.

1924. Stephen H. Straw, D.Sc., The University, Manchester, 13.

1924. G. A. Sutherland, M.A., Dalton Hall, Victoria Park, Manchester, 14.

1938. H. Frankland Taylor (Life Member), Innisfree, Lynne Road, Disley.

1937. W. H. Taylor, Ph.D., D.Sc., 30, Broadway, Withington, Manchester, 20.

1919. F. H. Terleski, Oakwood, Hilton Lane, Prestwich, Manchester.

1921. Professor F. C. Thompson, B.Sc., M.Sc., D.Met., The University, Manchester, 13.

1922. Franklin Thorp, Birchdene, Whitefield, Nr. Manchester.

1942. H. T. Thorp, " Beechwood," Pinfold Lane, Whitefield.

1938. Professor A. R. Todd, D.Sc., Dr.Phil. nat., D.Phil., Chemical Laboratory, Pembroke Street, Cambridge.

1942. Dr. L. S. Torrance, 2, Emma Street, Waterloo Road, Cheetham Hill, Manchester, 8.

1931. F. C. Toy, D.Sc., Tregays, Fletsand Road, Wilmslow, Cheshire.

1936. Miss H. I. Tuer, 3, Holly Avenue, Cheadle Hulme, Cheshire.

1931. H. A. Turner, M.Sc., A.I.C., (Life Member), Ministry of Supply, Chemical Defence Research Station, Porton, Wilts.

1944. Miss Emily Verity, B.Sc., 19, Wellington Road, Fallowfield, Manchester, 14.

Year of Election.

1921. H. Walkden (Life Member), The Raft, Derbyshire Road, Sale, Cheshire.

1944. R. D. Waller, M.B.E., M.A., Extra-Mural Department, The University, Manchester, 13.

1924. C. Walmsley, M.A., 6, Studley Avenue, Halifax, Nova Scotia.

1936. Professor T. B. L. Webster, M.A., (Life Member), The University, Manchester, 13.

1942. Professor F. E. Weiss, Easedale, Woodway, Merrow, Guildford.

1943. Frank W. Whaley, M.Sc., 126 Shaw Heath, Stockport.

1940. D. E. Wheeler, B.Sc., Ph.D., Halloween, Grove Avenue, Wilmslow.

1919. A. F. Williams, Eastwood, 28, Alardle Road, Sale, Cheshire.

1944. Miss Mary Winstanley, 6, Caldy Road, Pendleton, Salford, 6.

1920. J. C. Withers, Ph.D., A.I.C., The Shirley Institute, East Didsbury, Manchester, 20.

1916. J. K. Wood, D.Sc., F.I.C., 29, Altrincham Road, Gatley, Cheshire.

1923. George E. Yarrow, M.Sc., A.I.C., Dayspring, 13, Lynton Park Road, Cheadle Hulme, Cheshire.

This list is in conformity with the records of the Society, but members would perform a service in notifying any changes to the Assistant Secretary.

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M = Memoirs. P = Proceedings.